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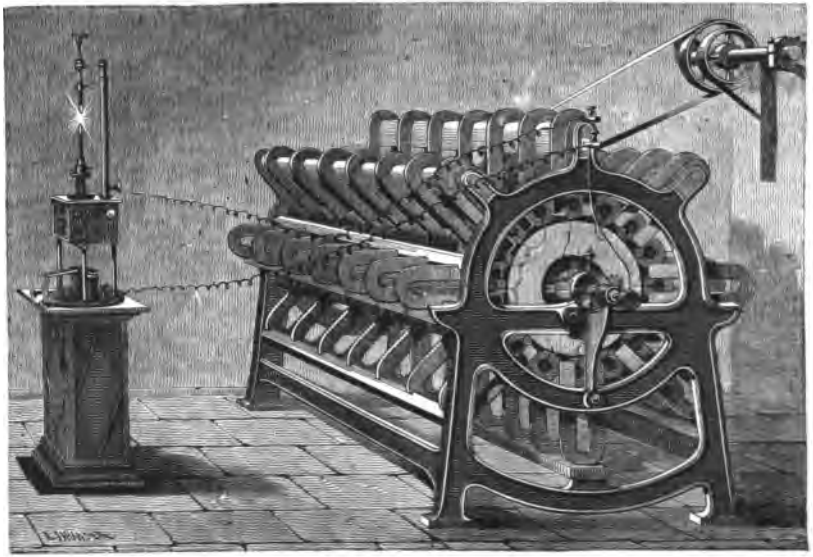

HOLMES-ALLIANCE LIGHTHOUSE MACHINE.

ELECTRIC LIGHTING

AND

ITS PRACTICAL APPLICATIONS

WITH RESULTS FROM EXISTING EXAMPLES

BY

J. N. SHOOLBRED,

B.A., M.Inst.C.E.

With Illustrations

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HARDWICKE & BOGUE, 192, PICCADILLY, W.
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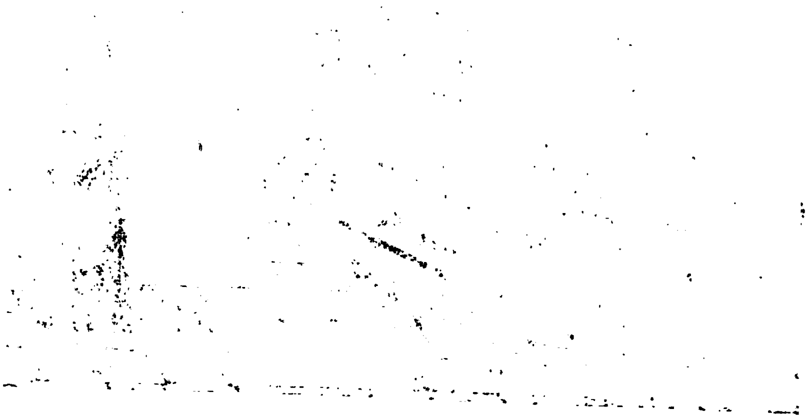

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ELECTRIC LIGHTING

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ITS PRACTICAL APPLICATION:

WITH RESULTS FROM EXISTING EXAMPLES.

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BY

ames elson
J. N. SHOOLBRED,

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ELECTRIC LIGHTING
AND
ITS PRACTICAL APPLICATION.

CHAPTER I.

HISTORICAL AND DESCRIPTIVE.

The application of electricity to the production of light is of but recent date, even as a scientific discovery; and as a matter of practical use for commercial purposes, it goes back but a very few years.

Sir Humphrey Davy, at the Royal Institution in 1810,* by breaking the continuity of the circuit of an electric current emanating from a battery of 2000 cells, and by separating slightly the two extremities of the broken circuit, produced a most brilliant light in an arch-like form in the intervening space. The name of the "voltaic arc" has been given to this strip of light; while that of "electrodes" has been assigned to the two points between which the arc is formed. The temperature of this luminous space was found to be so high, as to necessitate the points at either extremity of it being of the most refractory substance to prevent their being fused by the heat. Various substances have been tried, but two carbon rods, first used by Sir Humphrey Davy, have been found to answer the best: platinum, kaolin, and other substances have also been employed. In the voltaic arc produced between two carbon points, a large portion of the light, it is generally supposed, is due to the passage of incandescent particles of carbon across the space between the points.

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* Lecture at the Royal Institution on "The Electric Light," by Prof. Tyndall, Jan. 17th, 1879.

It can be readily understood that, brilliant as was the result of Sir Humphrey Davy's experiment, to produce electric light by the chemical means adopted, it was too costly for aught save experimental purposes. Its more general production lay dormant therefore pending the discovery of a more economical producer. It was not till 1831, that the great and important discovery of Faraday of induced currents first foreshadowed it. In July 1820 Œrsted, a Dane, by showing that a magnetized needle was affected by the proximity of an electric current, proved the analogy which existed between electricity and magnetism. Ampère and Arago followed it up, and demonstrated more clearly the interaction between the two kinds of currents. But it remained for Faraday, following in their wake, to show that a magnet could create an electric current; or more exactly, that the approach or retrogression of a magnet to or from a bar of soft iron with thin copper wire coiled round it, or, as it is generally termed, an electro-magnet, would induce an electric current in the latter.

The simple apparatus, causing the revolution of such a coil before the poles of a permanent magnet, constituted in fact the first magneto-electric machine—the mechanical motor required to give practical effect to Sir Humphrey Davy's discovery; and which dispensed with the use of any battery or chemical agency. Many years, together with the work of many minds, were still to be spent before this scientific discovery of Faraday's was to be moulded into such a shape, as to fulfil the requirements of practical and regular application.

Pixii, in Paris, in 1833 constructed a machine in which, by means of a hand-winch, the poles of a horse-shoe magnet were made to revolve rapidly in front of the ends of a double induction coil. Saxton, and afterwards Clarke, inverted this arrangement, and caused the coil, the lighter of the two, to revolve instead of the magnet.

In apparatus of this nature it will readily be seen that the nature of the current induced in the coil, whichever be the revolving element, will be subjected to a series of reversals in direction consequent upon the proximity alternately of the positive and of the negative pole of the magnet. The resultant current is therefore what is termed an "alternating" one.

If it is desired to convert this current into one having a regular, uniform direction, or what is called a "continuous" one, recourse must be had to a device termed a commutator; which takes off each kind of electric current separately.

The presence, or not, of this commutator with a machine at once divides all electric-light machines, whatever be the nature of their construction, into two classes; those of the "continuous," or of the "alternating" direction current.

L'Abbé Nollet, professor of natural philosophy at the Military School at Brussels, perceiving that a powerful electric current might be obtained by a combination of a number of Clarke's machines acting together, devised, about 1849, such an apparatus; its ultimate object being the decomposition of water. Unfortunately he did not survive to see the full success attained by his machine.

The machine, as constructed, consisted of six circular sets, each of four compound horse-shoe magnets, fixed symmetrically; they were arranged on a wooden and iron frame, each set being placed vertically with a space separating it from the next one. In this intervening space rotated a light brass wheel with twenty induction coils arranged round its periphery, which were acted upon by the horse-shoe magnets on either side of it, and in close proximity to which it revolved. From each of these coils the two wires were taken to platinum electrodes, placed in as many bottles as there were coils. All the rotating discs were placed upon a single axle, which was driven by steam power.

Six of these machines were made, and in 1853 taken to Paris under the auspices of the Société Générale de l'Électricité. A public trial of them, to disengage gas for illuminating purposes by the decomposition of water, took place there in the latter part of that year in the courtyard of the Hôtel des Invalides. The illuminating-gas bubble proved a ridiculous failure; and the question then arose as to what to do with the machines.

Mr. F. H. Holmes, who was present at the trial, suggested that they should be utilized in the production of the electric light; and he was empowered to make the necessary alterations for the purpose. A fortnight later at the same place he was enabled, with the aid of one of Duboscq's old form of lamps, to produce a strong and steady light. He made use of a continuous-direction current, having devised a complicated commutator for the purpose, and drove the electric machine at the rate of 700 revolutions per minute. M. Joseph van Malderen, originally employed under Nollet, and who subsequently as foreman engineer (contremaître ingénieur) of the Compagnie de l'Alliance put up the electric-light machines in the French lighthouses, assisted in making the alterations requisite. On this memorable occasion many scientific and other well-known persons, both English and French, were present; amongst whom were Lord Howard de Walden, Wheatstone, Brewster, Becquerel, Leroux, Devigne, Duboscq, &c.

In 1854 Holmes designed a machine expressly for the production of the electric light; it was constructed in the Rue Fontaine St. Georges, at Paris. In April 1857 took place the trials of the Holmes machine at Blackwall, under the direction of the Trinity House. Faraday was present, and was so pleased at this the outcome of his own discovery, that he exclaimed to Holmes: "It is my baby, you know, but you have made a man of my infant." This growth to man's estate had taken over a quarter of a century!

The result of these trials, extending over three months, proved so satisfactory to the Brethren of the Trinity House that on December 8, 1858, the South Foreland lighthouse, near Dover, was first lit up by the electric light by one of Holmes' machines; which later on was transferred to Dungeness.

Meanwhile, in France the Compagnie de l'Alliance was being formed about 1859 to take up the construction of electric-light machines, based upon the arrangement of Nollet. After satisfactory trials in Paris, the southern of the two lighthouses at Cape La Hève, near Havre, was lit up by electricity on December 26, 1863, and the northern one on September 1, 1865; since which dates respectively electricity has been regularly used as the illuminant in both. The lighthouse at Cape Grisnez, near Calais, followed on February 15, 1869.

The important part in electrical machines, which is played by the induction coil, has no doubt been remarked. This induction coil, or armature, or electro-magnet, consists of a length of copper wire wound spirally, generally in a transverse direction, round a bar or tube of soft iron. In 1854 Dr. Werner Siemens, of Berlin, introduced a very important modification in the arrangement of the armature, by coiling the wire lengthways upon the body of a ⊢⊣ shaped core of soft iron. Owing to the extremely small space required for its rotation, this armature may be kept within a region of strong magnetic force; and a much more powerful current developed than would be the case with an armature with the wire coiled transversely round the cylinder. By taking the current induced into a Siemens armature from small steel magnets, and passing it through a soft-iron electro-magnet to another Siemens coil, Wilde in 1865 obtained an ultimate current of much greater intensity than was the primary one. In some cases, to augment it still further, he has added a second, and even a third, electro-magnet and coil.

But electro-magnets were soon destined to play a still more important part in the future construction of electric machines.

In 1867 Dr. Werner Siemens, Sir Charles Wheatstone, and Mr. S. A. Varley made almost simultaneously the following important discovery; and which Sir Charles Wheatstone and Dr. C. Wm. Siemens each announced, independently and without the previous cognizance of the other, to the Royal Society on the same evening.

If an induction coil be made to revolve in front of a soft-iron electro-magnet, instead of before a permanent magnet, as in the earlier machines, the small amount of residual magnetism always latent in the iron, especially if it has been once magnetized, causes feeble currents to be induced in the coil; and, if these currents, or a portion of them, are sent round the iron bar, i. e. into the wire surrounding it, the magnetization of the iron is increased. This again produces a proportionate increase in the induced currents in the coil; and thus, by a series of successive mutual actions, intense magnetization and very powerful currents are produced. Machines constructed upon this principle of reaction (i. e. in which electro-magnets only are used) have been termed "dynamo-electric" machines, as indicating that dynamical force is converted into electricity; and which is gradually augmented in intensity. While for the older form, where permanent steel magnets are employed, the term "magneto-electric" machine has been retained; their power being limited to the strength of the magnetization of the permanent magnets made use of. This discovery, by adding considerably to the power of electric machines, led to a corresponding diminution in their bulk and also in their costliness. Almost all of the more recent machines are "dynamo-electric" in construction, and are based upon the principle of "mutual reaction."

Ladd, who was present on the occasion of the announcement just referred to, took advantage of the principle of "mutual reaction" in a machine which he was then at work upon, and which he exhibited at the Paris Exhibition of that year. It consisted of two flat-bar coils, placed horizontally one over the other, and so arranged as to form but one electro-magnet, and with a Siemens armature revolving at each end of the coils; the first coil serving to make the electro-magnet by its reaction, while the current from the second coil was passed off to produce the light.

This principle of mutual reaction soon became acknowledged as a great step in advance. Siemens adopted electro-magnets instead of the permanent steel magnets he had previously made use of with his armature. In 1871, Gramme, who had also previously constructed a magneto-machine, brought out his earliest form of dynamo-machine, making use of two coils, in the same way that Ladd had done. The coils, however, were different in form; consisting of an annular soft-iron core, with the wire wound transversely around it, and divided around the ring into the requisite number of segments.

Pacinotti of Pisa, seems to claim priority, as far back as 1860, for this form of annular coil used by him in his machine; but whether the two forms are quite alike appears doubtful.

Gramme has since abandoned the use of two coils, and uses but one in the improved form in which this single-light machine is now ordinarily constructed (A, Fig. 2, Plate II.).

Among the machines which followed, are two well known in the United States, the Wallace-Farmer, and the Brush; and which, together with the Siemens and the last-named Gramme, are apparently the best known, and the most extensively applied of the single-light dynamo-electric machines.

A distinguishing feature of the machines belonging to this second stage is, that they produce currents of considerable intensity, all of which are collected upon the circumference of a circular disc termed a commutator; the currents circulating upon one half of its circumference being opposite in magnetic direction to those upon the other half; a separate contact brush serving to carry off the current from each half. The currents from these machines thus pass off in one continuous direction, and are not subject to a constant series of reversals in direction as with the earlier machines. The currents are generally supplied for the production of a single electric light. The rate of rotation required for them in general is very high, from 700 to 1000, and even more, revolutions per minute, according to size. This rapid motion often causes trouble with the commutator brushes, which heat and wear in consequence.

About 1874 the attention of electricians began effectually to be turned to the production of several lights from one electric machine. Lontin in this year produced a compound machine (Fig. 1, Plate II., and described farther on), together with a regulator sufficiently delicate for the purpose. Then in 1876, Jablochkoff devised his now well-known "candle" as a simplification of the arrangement of the carbons, or electrodes, between which to produce the light; he found himself obliged to make use of the now ancient Alliance magneto-electric machine, as the only one available which could supply the alternate-direction currents necessary for his regulator. Later on Gramme devised his latest form of dynamo-machine (B, Fig. 2, Plate II.), to perform this duty more efficiently than did the Alliance machine; and it is this last that is now almost always employed where the Jablochkoff candles are made use of as the regulator. Still more recently, 1878, De Meritens has devised a magneto-machine (Plate I., Fig. 1), a modification and improvement upon the Alliance one, much reduced in size and weight; and which hopes to compete with the small and compact dynamo-electric machines of the present day.

In all these machines serving for the production of several lights from each, and which may therefore be termed "many-light" machines, it has been found most convenient to construct them so as to give off currents alternating in direction; which in practice seem more suitable for the steady continuance of several lights, than do those currents which are continuous in direction.

Electric lighting, it will readily be seen, has only attained to its present development by certain marked stages of progress; each period represented by clearly defined and distinctive characteristics, both in the apparatus employed and in the use to which they were applied.

These stages may be briefly described as—

1st. That of lighthouse illumination by the Holmes and by the Alliance magneto-electric machines, giving off currents alternating in direction, and producing a single very powerful light.

2nd. That of dynamo-electric machines producing a single light each, for industrial purposes generally, in addition to lighthouse illumination. The Siemens, and the earlier Gramme, are the best known in Europe of these machines; while the Wallace-Farmer and the Brush claim most attention in the United States.

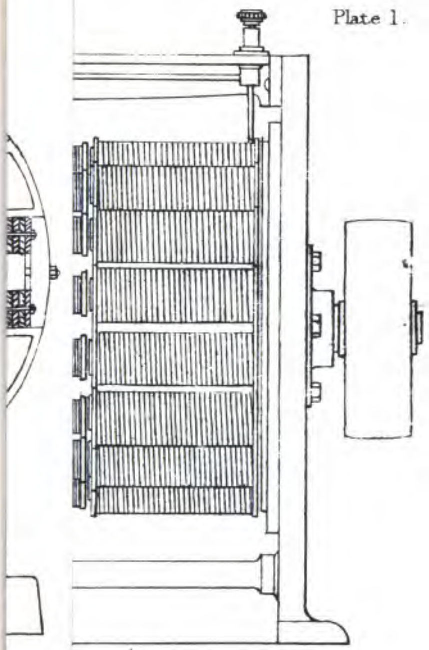
3rd. That of machines both of magneto and of dynamo construction, and generally (though not necessarily) giving off alternate-direction currents; and which afford facilities, if provided with suitable lamps, for the production of a number of lights from each machine. Besides the already-named Holmes and Alliance machines, and their recent and more compact successor, the De Meritens (all being of magneto construction), there are the Lontin (double), and the Gramme (double), which also effect this much-desired object. In all these machines the current given off is alternating in direction. The two last-named machines, though dynamo in construction and in principle, are by some persons classed as magneto-machines in their operation, inasmuch as the initial or generating machine of each maker acts like a permanent magnet to its second or dividing machine, and affords to it a supply of electricity. Still, it may be replied, while the "generator" in each case most certainly acts on the dynamo principle, the "divider" does so also, as it greatly augments the electric current received from the former before it delivers it as its final output. Wilde has also devised a single machine of "dynamo" construction (Plate I., Fig. 2); which also carries out the augmentation of the electric current, the principle of his earlier "magneto" machine.

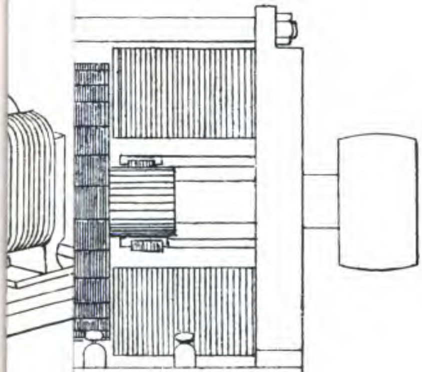
In order to test the relative efficiency of certain electric-light machines for lighthouse illumination, a series of experiments were made by the Trinity House at the South Foreland Lighthouse. They were carefully devised and carried out in 1876–7 by their engineer, Mr. James N. Douglass. They consisted in comparative trials between the Holmes, the Alliance, the Gramme (early model dynamo-machine with two coils), and the Siemens machines; the two first-named representing the old obsolete magneto-electric machines, and the last-named the dynamo-electric form of construction. The Siemens machine was considered to have performed the best; a result which ought not to excite surprise when placed in such company. Though the improved dynamo-electric Gramme (the single-coil one, described farther on) was not experimented upon in the trials, Mr. Douglass at the end of his Report refers to an inspection which he made in Paris of the performance of one of these machines (type "A"); he did not, however, consider it superior to the Siemens machine (type "B"), corresponding to it in size. These experiments are very important; as they afford a means of comparison between the efficiency of the first class of electric-light machines, the magneto-electric, and those of the second class, the dynamo-electric.

The value of this comparison has been still further enhanced by the experiments of the Committee of the Franklin Institute in Philadelphia, on dynamo-electric machines, carried out in 1877–8, and recently made public. They had under comparison the Gramme (type "A"), the Brush (large and small size), and the Wallace-Farmer (large and small size). Preference is finally given to the small Brush over the Gramme, which is admitted to have run it very close. The grounds for the preference seem, however, somewhat paradoxical.

In the following chapters a few of the machines, as also of the lamps, most employed in electric illumination will be noticed; together with some observations as to the carbons used, and likewise respecting the motive power required. These will be followed by some remarks on the luminous intensity of some of the forms of electric illumination, pointing out some of the distinctive peculiarities of each; and by certain examples of practical applications, together with their financial and economic results.

Plate 1.





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CHAPTER II.

ELECTRIC-LIGHT MACHINES.

Magneto-electric Machines.—The earliest forms of electric-light machines were constructed, as has been seen, with permanent magnets of steel. They were made by Holmes in London for the English lighthouses at the South Foreland near Dover, and at Souter Point in Durham; and by the Alliance Company in Paris for the French lighthouses at Cape La Hève near to Havre, and at Cape Grisnez not far from Calais, and also for those in Russia at Odessa, and at Port Said, the entrance to the Suez Canal. They are all so similar in construction, that one description will serve for them all, and which the drawing in the frontispiece will serve to illustrate.

The Holmes-Alliance Machines.—The machine at Cape La Hève (constructed by the Alliance Company) has on each cast round frame eight rows of compound horse-shoe magnets fixed symmetrically. There are seven of these frames each separated from the next by a space. Within the six intervening spaces are placed six wheels, each carrying at its circumference sixteen coils, corresponding to the poles in each circular set. Each soft-iron core has its magnetism consequently reversed sixteen times during each revolution by the influence of the sixteen successive pairs of poles between which it passes, causing the same number of currents in alternate directions to be generated in the coils. These currents are transmitted unchanged to the carbon points, the positive ones being collected on the axis of the machine; while a concentric, but insulated cylinder is used for the negative ones.

This machine is large and cumbrous, being 5 feet 3 inches long, 4 feet 4 inches wide, and 5 feet high; it weighs about 2 tons, and cost 450*l.* Its illuminating power, when driven at a speed of 400 revolutions per minute, from a steam engine of 8 H.P., with an expenditure of somewhat over 3 indicated horse-power, is about that of 2000 standard sperm candles per hour. Two complete apparatus and engine, as just described, are provided at Cape La Hève; one for the northern and one for the southern lighthouse.

The use of the large, old-fashioned, and comparatively weak machines of this Holmes-Alliance stage may be said to have passed away, being only retained in the lighthouses above mentioned. Their only recent application, and that was but of short duration, was to provide the alternate-direction currents necessary for the Jablochkoff candles when first introduced; and until M. Gramme had devised a suitable machine for their proper supply.

The De Meritens Machine.—Quite lately, however, a modified form of machine, much reduced in size and weight, has been designed by M. de Meritens; in order to compete with the small and compact dynamo-electric machines of the present day. It consists (Plate I., Fig. 1) of eight compound horse-shoe magnets, arranged lengthwise around, and resting across two circular frames. Before the ends of these magnets rotates a wheel of light construction, having a series of sixteen flat-shaped coils arranged upon its periphery; the cores of each coil being composed of no less than fifty thin wrought-iron plates. The compound ⊢⊣ shaped cores of these coils, when placed end to end, though insulated from each other, but with a copper pin between each pair, and arranged round the periphery of the wheel frame, really form themselves into one continuous annular core, like that of the coil in the Gramme machine. Owing, however, to the comparative shortness of each De Meritens coil, and to its being insulated from its neighbours, currents of opposite nature (occasioned by the reversals, when passing severally in front of the different poles) are not, to any extent, set up in the cores of the coils; as is said to be the case in the continuous annular core of the Gramme coil.

There remains, also, with them the great advantage, that the coiling, instead of being effected upon a solid and continuous ring (which is found in practice to entail considerable inconvenience), is done upon the small compound plate-core belonging to that particular segment; which can easily be removed from the general ring for this purpose, as also for any other repairs. No commutator or collector is required with the machine.

The De Meritens machine claims to unite in itself, in its action, not merely the alternately reversing currents of the magneto Alliance machines, but also those induced by the arrangement of the Gramme coil. The result of this combination reduces the necessary motive power to nearly one-fifth of what is required in either the magneto machines of the Alliance Company, and to much less than in most of the dynamo machines; likewise very little heating occurs, though the machine is driven at a very considerable speed.

Dynamo-electric Machines.—The very important discovery in 1867 of the principle of reaction between electro-magnets, and the gradual augmentation in the intensity of the electric current by these repeated passes, soon led to abandonment of the large, costly, permanent steel magnets which had been used as a storehouse whence to draw the electric current; their place being taken by small, compact, and comparatively inexpensive electro-magnets. These, though very weak in their initial action, were soon by reacting on one another worked up to a much higher electrical efficiency than would have been produced from permanent magnets of a much larger size. The natural result was an electrical machine much smaller, more compact, and more economical.

Though more powerful, bulk for bulk, these "dynamo" machines are subject to certain irregularities in the output of the electric current; and also, at times, to considerable heating of the coils, due probably to the very great internal resistances developed in them, and which render this class of machines liable to interruptions in working. "Magneto" machines are considered by some to work with more regularity and steadiness in the current generated, and with much less chance of a cessation in their working; a quality which may, in some cases, more than compensate for their extra size and costliness. Against them, however, it may be urged, that the permanent magnets gradually deteriorate and lose a portion of their magnetic power. Where the machine is used regularly, night after night, as in lighthouses, this does not amount to much; but when the illumination is liable to suspension for a lengthy period, as during the summer months, the loss during this period may become a serious inconvenience. This loss, however, is stoutly denied by some; as the deterioration, they say, can be rectified by half an hour's working of the machine.

Of electric-light machines of "dynamo" construction, the following are among some of the best known and the most extensively used, in this country at least.

The Siemens Machine (Plate I., Fig. 3).—It consists of an induction coil, with the convolutions of the copper wire wound lengthwise with the cylinder, in the form known as the modified Siemens armature. The coil is made to revolve by mechanical means between curved iron bars, which are the prolongation of the cores of large flat electro-magnets placed on either side of the induction coil; the north pole of the system being midway between the two upper electro-magnets and directly over the axis of the coil, and the south pole in a similar position below the axis upon the bar between the lower magnets.

The portion of the coil which during its revolution is travelling downwards, has (with the above arrangement) positive currents induced in it; while the ascending half of the coil is subjected to negative currents, but both in the same direction as regards circuit. The arrangement of the poles may, however, be exactly the reverse of the above.

		Revolutions per Minute.	Illuminating Power, Standard Candles.	Actual Horse-power absorbed.	Weight.	
					cwt.	qrs.
The Siemens machine is, as stated by the makers, usually made in the following sizes and capacities, viz. ..	A	850	1,200	2	2	2
	B	650	6,000	4	3	3
	C	360	14,000	8	11	2

The machine represented in the diagram is the type "B," of 6000 standard candles nominal power.

The light at the Lizard Lighthouse is produced by a Siemens machine and lamp. Many other applications of this system for industrial and military purposes exist in this country and on the Continent.

The Gramme Machine.—This machine in its earliest development was composed of round electro-magnet bars placed vertically, with double induction coils, one of which served to react upon the magnets; as previously referred to in Chapter I. Its very existence is nearly forgotten; and it is referred to here merely to mention that this is the form of Gramme which in the Trinity House experiments was pitted against the Holmes, the Alliance, and the Siemens just described.

The type of Gramme here about to be described is the second form, with a single induction coil, and supplying a continuous-direction current to a single light; a machine very similar in construction and principle to the Siemens one just described. It is the machine referred to by Mr. Douglass, in the concluding paragraphs of his Report upon the Trinity House experiments at the South Foreland, as having been the object of his special visit to Paris.

It is composed (Plate II., A, Fig. 2) of an induction coil having for its core a ring or cylinder of soft iron, which is made to revolve mechanically between two round bars, each forming the core of a pair of electro-magnets. These bars are placed one directly over, the other beneath the axis of the coil and lengthwise with it. Each bar extends from one cast end-frame piece to the other side of the machine; while its middle is clipped by a sort of ring of cast iron, which serves to divide the coils wound upon the half bar on either side of it, and thus forming them into two electro-magnets. These are so arranged, that the pair on each bar have like poles next to each other at the centre next to the cast ring, which serves as a double pole to convey the combined electricity to the revolving induction coil, by means of its jaw-like projections which are splayed over the coil, so as to embrace it as closely as possible without touching it.

As in the Siemens machine, the double pole of the upper bar is opposite in character to that of the lower one. Similarly also are the induced currents in the descending half of the revolving coil like in nature to the upper pole; while those in the ascending half follow the lower pole. Two brushes, tangent to a circular commutator, placed on the induction coil shaft, carry off the electricity in one continuous direction.

		Revolutions per Minute.	Illuminating Power, Standard Candles.	Actual Horse-power required.	Weight.		Cost.
					cwt.	qrs.	£
The Gramme machine is stated by the makers to be usually made in the following sizes and capacities, viz.	M	1,600	2,000	1½	1	2	70
	A	900	6,000	2½	3	3	100
	C	700	15,000	5	8	0	300

The machine shown in the drawings is the type "A" of 6000 candles illuminating power, and it is the one generally made use of in industrial works and other similar applications.

In France a number of industrial works, such as spinning and weaving mills, ironworks, open yards, and railway goods stations, have been lit up, each by a number of single-light Gramme machines. The result has been generally satisfactory; but the expense must be greater in each case than if the same number of lights were supplied from a single machine.

The Wilde Machine.—This must not be confounded with the machine first referred to under this name in the preceding chapter; where small steel permanent magnets with a Siemens armature revolving between them, passed a current through electro-magnets to a second Siemens coil, and so to be utilized.

Wilde's "dynamo" machine (Plate I., Fig. 2) consists of two cast-iron circular frames, placed vertically and kept the requisite distance apart by stay rods. On the inside face of each disc, and consequently opposite to one another, are fastened at equal distances round each periphery the ends of sixteen round bar electro-magnets, which project out lengthways into the space between the circular frames; each set nearly closing up the space between the frames. In the central interval which is left, is placed vertically a round cast-iron disc, keyed upon a shaft running through bearings in the centre of each of the circular frames, and projecting beyond them, to carry the necessary driving pulleys, commutators, &c. Through this round rotating cast-iron disc are passed sixteen soft iron cores, projecting on either side of it up to the ends of the fixed electro-magnets already referred to, and corresponding in position upon the disc to theirs upon their respective frames. The portion of each core upon either side of the disc has its separate coil of wire upon it.

Thus upon each side of the rotating disc is a series of sixteen fixed electro-magnets, and of a similar number of revolving induction coils. The two halves into which the machine is thus divided may be kept perfectly distinct; a portion of the coils serving to react upon certain of the magnets, and to pass the augmented current on to the other portion, whence it is utilized in the manner required.

The Wallace-Farmer Machine.—This machine, known and used in the United States for some time back, is gradually coming into application in this country. It is shown in Plate I., Fig. 5. It presents, in appearance at least, some similarity to the Wilde machine. Upon its central rotating cast-iron disc it carries, projecting on either side, twelve double coils; while the fixed electro-magnets are but two in number, projecting from each end-frame, somewhat as in the Gramme machine. The upper pair of electro-magnet bars have their opposite poles facing the central rotating coils; as have also the lower pair of electro-magnet bars, except that the pole exposed in the lower bar is the reverse of that in the upper bar immediately over it. By this arrangement the machine is practically a double one; each half with its commutator being capable of being used independently of the other.

The Brush Machine, though used in the United States, is not so far known in this country. It is the machine to which the committee of the Franklin Institute last year in their report "On Dynamo-electric Machines," after a lengthened series of experiments, gave the preference over the "Gramme" and the "Wallace-Farmer" machines. The diagram (Plate I., Fig. 4) is taken from the above report. The Brush machine is composed of a pair of fixed horse-shoe electro-magnets placed with their like poles facing each other, with a circular armature rotating between them. This ring is not coiled continuously, as in the Gramme coil, but in portions, leaving alternate uncovered spaces between each segment, which are covered by iron extensions from the ring; as in the Pacinotti machine, to which it is said to bear some resemblance. The two upper electro-magnet bars have their like poles facing the central rotating coil; while in the lower bars they are also similar to one another but opposite in character to those of the upper bars; each pair of bars thus practically forms extended poles of opposite character.

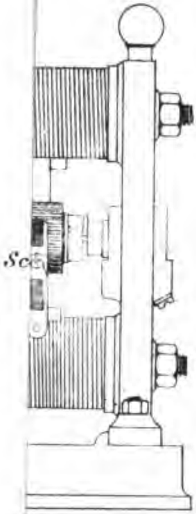
The preceding "dynamo" machines may be classed as belonging to what is termed "single-light" machines;

the sole utilization of the current generated being the production in actual practice of a single light. Although certain attempts, especially with the three last-named machines, have been made, and it is said with a fair amount of success, to support a series of lights from them, yet these trials can hardly be said to have passed into the domain of practical application.

The "dynamo" machines, which are about to be described, have fairly earned for themselves by actual and regular working for a long period the title of "many-light" machines. This is shared, however, also by the "magneto" machines of the Holmes-Alliance form, and by the De Meritens, their more compact successor. The distinguishing feature of the Lontin, and of the Gramme "many-light" machines, is that they are practically two machines; though perhaps under certain circumstances and with due proportions, the two might be combined upon one frame.

The Lontin Machine.—M. Lontin, unlike M. Jablochkoff and M. Gramme, each of whom attacked only a portion of the question of the divisibility of the light, has boldly faced the entire of the difficulty, including the lamps or regulators, and has offered a very satisfactory solution of each part of it. He has designed a special form of machine, or rather two distinct machines, to effect the object desired. In the first (marked A on Fig. 1, Plate II.), which may be termed the "generating" machine, the electric currents, feeble in intensity, are excited; they are passed off in one continuous direction to the second or "dividing" machine (marked B), which, after greatly augmenting their intensity, permits of their being collected from off its exterior casing, in a form divided and subdivided almost at will, and alternating in direction; this last being, in his

Plate 11.



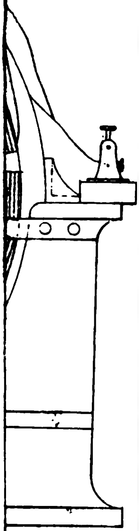
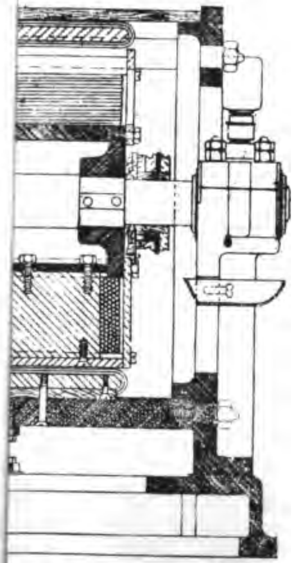


Fig. 2.



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opinion, the description of current most suited for giving a pure, steady light, and one not subject to reproduce sympathetically the disturbances occurring in other lights which are on the same circuit. The latter object M. Lontin effects with several forms of lamp, some being modifications of other systems, while others are entirely original in their mechanism and regulating apparatus.

The "generating" machine (A) consists of a horse-shoe electro-magnet, having its two arms placed vertically upwards. Between these arms rotates an induction coil, in form like a pinion; the cylindrical teeth, round which the coils are made, are fixed radially into a core or revolving axle of soft iron. A number of these pinions, proportionate to the required strength of the machine, are added side by side on the core, each pinion forming a complete circuit of itself. In the arrangement of these pinions upon the core common to all, it will be noticed that the corresponding teeth of these several pinions are not ranged in a horizontal line lengthwise along the revolving shaft, but in a spiral. By this means any interruption or interval, between the passage before the poles of the electro-magnet of one set of teeth of the induction coil and that of the succeeding set, is avoided. Two friction rods collect one the positive, the other the negative currents, which are passed off through the coils of the electro-magnet, thereby intensifying its action; and so in one continuous direction to the second machine.

This second or "dividing" machine (marked B on the drawings) consists of a revolving drum carrying, fixed exteriorly like the spokes of a wheel, a series of electro-magnets; into the coils of which the currents from the "generating" machine (A) are passed, and which are always kept thereby in magnetic saturation. This magnetic wheel revolves within a fixed wrought-iron cylinder, having on its inside a number of induction coils corresponding to that of the radial spokes in the revolving wheel. The coils of these spokes are all coupled together, but in such a manner that while one spoke-magnet has its positive pole at the outside extremity next to the induction coils, the succeeding spoke will present at the outside end its negative one; and so on are the spokes made to alternate in their poles round the circumference of the revolving wheel. The result is that the latter during its passage induces a number of currents alternate in direction, and equal in number to half that of the spokes. Each of these currents is collected directly and separately upon the fixed exterior drum, and conveyed to a manipulating frame outside, where by suitable arrangements the various elementary currents may be coupled and combined together in one, or in any desired number of circuits.

The apparatus in the drawing having twenty-four spokes, can, by coupling them in pairs, produce twelve circuits, or any lesser number which may be desired. And furthermore, the entire of the current of each circuit may be devoted to a single lamp, or to the production of a series of as many lights as it can support. Facts which seem to indicate that an electric supply may be broken up and divided into a series of separate lights, where the number as well as the luminous power of each can be varied at will, only limited by the powers of production of the machine.

The double Lontin machine shown in the diagrams is of the type stated as capable of supplying a total illuminating power of 12,000 standard candles, if the generating machine is driven at 320 revolutions per minute, and the distributing at about 360; but a much larger illuminating power may be obtained if driven at a proportionately higher speed. The usual motor for this sized machine is an engine of 10 horse-power nominal; the number of lights generally produced, as at the Western Railway Terminus in Paris, varying from six to twelve. But as many as twenty-eight have been supplied regularly from a single generating machine at the Lyons Railway Station in Paris, supplying two dividing machines; and where a higher rate of production than the above was required.

The Gramme "Dividing" Machine (marked B, Fig. 2, Plate II.).—Reference was made a short time back to this the latest development of this machine.

To relieve M. Jablochkoff from the necessity of making use of the cumbrous and comparatively weak Alliance machine, and yet to afford a supply of alternating-direction currents, M. Gramme lately devised this machine to be supplied with a previously created electric current; his own continuous-current machine (previously described and marked A) serving as a "generator" for this current. The arrangement and the combination arrived at has a strong resemblance (superficially at least) to that previously arrived at by M. Lontin.

The machine (B) consists of a revolving cast-iron drum on a steel shaft, having eight electro-magnet flat bars placed radially like the spokes of a wheel; to this revolving system is supplied the electricity generated in one continuous direction by the generating machine (A). Upon a soft-iron cylinder, fixed exteriorly to this magnetic wheel, are wound a series of coils lengthwise with the barrel, and dividing up the entire cylinder into a number of segments—32 in the present instance; the current being taken directly and separately from each of these segments to form one or more circuits as desired; 32

being the maximum number in the above machine, though these are in practice coupled together so as to be reduced to four. The luminous intensity of this machine is of the type known as of 16,000 candles. As applied, in lighting a portion of the Avenue de l'Opéra in Paris, to 16 Jablochkoff candles, it is driven at 650 revolutions per minute, by an engine of 20 nominal horse-power.

Siemens has also devised an alternate-current "dividing" machine, which is similar in principle, it is understood, to the corresponding portion of the Gramme machine, though in appearance it resembles the Wilde. The single-light Siemens, already described, is used as a "generator" of the current.

Before concluding this brief notice of some of the electric-light machines, it may not be out of place to advert to a broad distinction which at present exists, temporary though it may be, between the machines, of "dynamo" construction at least, which are used for the production of a single light, and those which supply many lights; whether these latter machines be constructed with permanent or with electro-magnets. While the former, the single-light machines, give off continuous-direction currents, the many-light ones, at least those which have been successfully applied for any length of time, invariably make use of alternate-direction currents. Although it is admitted on all sides that several lights can be maintained on the same circuit with continuous-direction currents, yet it is a singular fact, that in actual practice alternate-direction currents are always had recourse to where a number of lights are required from one machine. Perhaps the latest example of this is the Rapieff, which began with the continuous-current Gramme; but which in regular work in the *Times* office abandoned that machine for the alternate-direction "dividing" one of the same maker.

Perhaps there may be something in the incessant reversals of the current, in what is termed the alternate direction, which may tend to cause a steadier and more equable flow, and one less liable to rushes and irregularities than with continuous currents.

Much stress is laid by some upon the loss of electricity through these constant reversals; and upon the consequent electrical economy of a continuous-direction current. From the gradual experience of practice with alternate-direction currents, and the use of longer circuits and more lights upon each (both of which circumstances are supposed to add to the loss), this diminution would appear to be considerably smaller than many imagine it to be. The difficulty of measuring exactly these alternating currents, where a galvanometer cannot be employed as with a continuous-direction current, tends to add to this uncertainty.

Theoretically, the most economical machine for supporting a number of lights ought to be a single (not a double) one, and one making use of continuous-direction currents. The solution of the problem, in this last sense; has been reached satisfactorily, as far as single lights upon each circuit are concerned. Its further extension to a number of lights may be found to depend more upon the lamp, or regulating apparatus, than upon the machine.

CHAPTER III.

LAMPS AND REGULATORS.

The substance, first found by Sir Humphrey Davy, and employed almost exclusively ever since, as sufficiently refractory to form the terminal points of the interruption in the electric circuit, between which points the electric light is produced, is carbon. As this material undergoes waste by combustion, it is necessary to devise some means by which the ends of the carbon sticks shall be continually kept the requisite distance apart; neither more nor less. If this distance is nicely adjusted to the length of the arc which is most suitable to the strength of the particular current employed, almost the entire of the light is emitted from the voltaic arc formed in the space intermediate between the carbon points. But little effect is visible upon either carbon rod; each being rendered incandescent for only a very short and imperceptible distance back from the carbon points. This, the most general form of illumination, is termed the *voltaic arc.*

If, however, the distance between the electrodes is made less than the length of the voltaic arc most suited to the strength of the particular current, or if the current be of an insufficiently high tension to support a voltaic arc of notable dimensions, then a portion of the force of this electric current seems to find vent for itself by illuminating, or rendering incandescent, the positive carbon (the incoming-current one, when the direction is constant)

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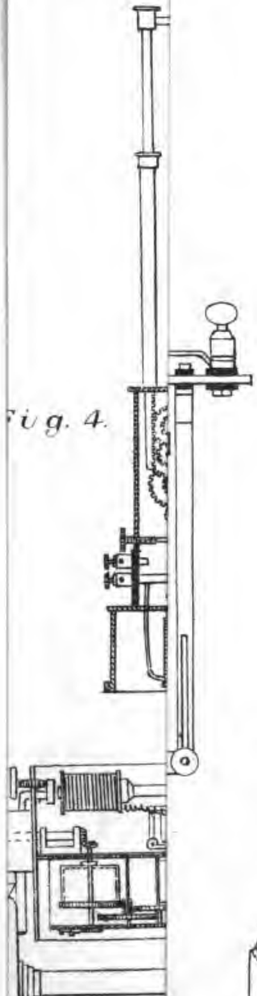

Fig. 4.

Plate III.

RAPIEFF

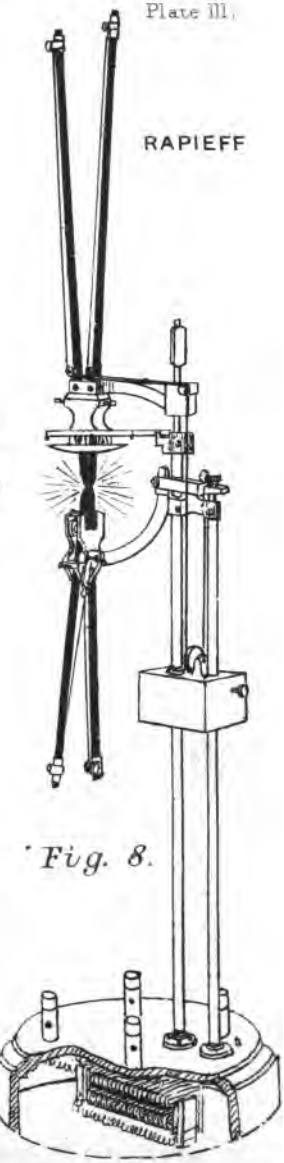

Fig. 8.

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for a very noticeable distance backwards from its point. This is termed illumination by *incandescence.*

Some substances, however, such as platinum, iridium, kaolin, are rendered incandescent without any rupture or break in the body; which itself is of such a non-conducting nature as to offer sufficient resistance to the electric current to cause its entire mass itself to become incandescent. In the following remarks, in this chapter, the phenomena connected with the use of carbon only will be considered; since this is the sole substance which is generally and commercially applied, at present at least, for the composition of the electrodes in electric illumination.

The apparatus devised to hold these carbons, whether in sticks or in plates, may be, in a general way, termed lamps. But these must be divided into two broad divisions; according to whether the carbons are movable and require some mechanism to regulate the movement suitably to the rate of combustion, or whether the carbons are fixed, and consequently can dispense with any such mechanism. In the former case they are termed *regulators;* for the latter "*candles*" has been used, and not inaptly. This last expression is of but recent date, as a fixed arrangement of the carbons has only lately come into use, and even yet its ultimate adoption in practice is still an open question.

REGULATORS.—The duty to be performed by these small apparatus is of a very important, delicate, and complicated character; so important, that unless the regulator fully complies constantly and continuously with the conditions imposed upon it, it completely stultifies the regular supply of the electric current which a machine of excellent quality may afford to it. Amongst the duties which these apparatus are expected to perform are:—

1. The regular and gradual approach of the carbons according to rate of combustion; and therefore a progress varying not merely with the strength of the current but also with the nature of the supply, whether in one continuous direction, or whether alternating in direction.

2. The approach and separation of the carbon points to create the electric spark in the first instance, and then to counteract the ever-varying irregularities of the strength and supply of the current during the period of illumination; and also to prevent these irregularities being felt beyond the lamp itself (a most important and essential point where several lights exist on one circuit).

3. The normal separation of the carbons according to the desired length of the voltaic arc, which is deemed suitable to the strength of the current employed.

The first-named duty is performed, in most apparatus, either partly or wholly by gravity, which necessitates the carbons being placed over one another. In some of the most recent forms, however, the carbons can be placed horizontally, or in any other position, and either in a direct line opposed to each other, or inclined towards one another, their approach being effected by mechanical action. The second set of duties are carried out almost universally by means of electro-magnets and armatures, contained generally in the base of the apparatus. The third duty is performed ordinarily by adjustment screws placed on the attachment of the carbon-holders, and which can be made to raise or depress the carbons at will, even during the period of illumination.

Of the earlier forms of lamp the most ingenious, those of Duboscq and of Foucault, though wonderfully sensitive and delicate, are now chiefly in vogue for laboratory experiments, for which these qualities render them especially qualified. In the actual applications to illumination that of Serrin is perhaps at present the most in use, where single lights only are desired from a machine; being simpler in construction than the two preceding and less liable to get out of order with rough usage. Besides being extensively used, this lamp may be considered as a type of a particular class; it is therefore here briefly described.

The Serrin Regulator.—In it (Plate III., Fig. 1) the carbons are placed vertically over one another, the upper carbon being made to travel by means of a rack and pinion attached to the bottom of its holder, and driven by a spring which is controlled by an electro-magnet placed in the base of the lamp. This electro-magnet, according to the force of the current passing into it from the main current, also attracts or rejects an armature, the effect of this oscillating movement being to cause the lower carbon-holder to rise or fall, according to the irregularities in the strength of the main current, which is itself producing the voltaic arc. The normal separation of the carbon points, to suit any required length of arc, is effected by raising or depressing the upper carbon-holder, by means of the screw placed at the top of its upright, where the horizontal arm is hinged.

This lamp, in the form and dimensions usually constructed by Serrin, admits of carbons which last only for about three and a half hours' consumption on an average. A modification of the lamp by *Suisse* allows, however, of carbons of sufficient length for twelve, and even sixteen hours', continuous burning without renewal; a fact of very considerable importance where the illumination is intended to last throughout the entire night. By a simple expedient, Suisse allows the rod of the upper carbon-holder to pass downwards through the bottom of the lamp-box; thereby avoiding the very inconvenient height which the lamp would otherwise assume through the much augmented length of the carbon rods. Generally, the lower carbon-holder is fixed, and consequently the luminous point descends with the rate of consumption of the lower carbon; a circumstance which is not found to entail any inconvenience worth mentioning in the majority of cases in actual illumination. If, however, it is desired to have the luminous point constant in one spot, this is readily effected, in some of the lamps, by making the lower carbon-holder movable; working upwards by means of a rack and pinion motion. Again, some of these lamps are constructed for naval use; so as to counteract the oscillations in position of the vessel, and to allow the lamp to retain its vertical position.

All these forms of the Serrin lamp may be adapted either to a "continuous," or to an "alternate" direction electric current. With them, however, no more than one lamp at a time can be used upon a circuit; the electro-magnet arrangement used not being sufficiently delicate to effectually suppress the irregularities transmitted by the current from passing from the first to the second lamp upon the circuit; the result in them being a reciprocating (in and out) action of the two lights. *Lontin*, however, desiring to retain the use of the Serrin lamp with his many-light machines, has remedied the defect just mentioned. The change, though slight in appearance, is a very radical alteration; it is so great that it actually inverts the action of this delicate portion of the Serrin apparatus in its original; interrupting the current where there was previously admission, and *vice versâ*. He makes use of two electro-magnets, in lieu of the one of the

Serrin; and, moreover, while the latter is placed upon the main current of the circuit, by the Lontin arrangement the lamp is upon a branch or shunt.

The Siemens (or Häfner-Alteneck) Regulator.—This instrument is extensively in use in Germany and in this country. In it (Plate III., Fig. 4) the two carbon-holders work together by means of a double pinion acting upon the rack of each holder. The large wheel actuates another pinion and wheel, which again sets in motion a third system; this last may be stopped or released by the movements of the prolonged upper end of an armature, acted upon by an electro-magnet in the base of the instrument. When the current becomes too strong, and the carbon points too near, the armature is attracted by the magnet; and the carbons are caused to separate. The second-named pinion gear, meanwhile, being allowed to act upon the first-named set, and so upon the carbon-holders.

This lamp, which may be arranged to suit either "continuous" or "alternate" direction currents, though it generally happens to be used with the former, is said to work very regularly: it furthermore is simple in construction, and can readily be kept clean and in good order.

The Lontin Regulators.—In the early stages, M. Lontin made use of the Serrin lamp, and indeed he does so largely still in certain cases, with the very ingenious modification of his own just referred to. He has latterly introduced two other forms of regulator, which have the two advantages of being independent of any particular position (the action of gravity being entirely dispensed with), and of allowing any length of carbon being used, and of providing therefore for any ordinary period of illumination without the necessity of a fresh supply of carbons. In one of these regulators, the travel of the carbons is effected by means of two endless screws with threads in opposite directions, one to each carbon-holder, which are thus caused to progress; the action of an electro-magnet causes these screws to revolve when required to do so. In the other regulator (the Mersanne, Plate II., Fig. 9), an electro-magnet causes a round bar running lengthwise with the carbons to revolve, which motion is imparted by means of bevelled gearing to small wheels at the extremity of the carbon-holders, and so propels the carbons gradually forward. These carbon-holders are fixed at about two inches from the carbon point, and the resistance which each current has to encounter is limited therefore to that due to this length, irrespective of that of the carbon.

The Rapieff Lamp.—This form of regulator has attained a certain amount of notoriety in this country, apart from its intrinsic merits, which appear to be considerable; owing partly to its striking and original external arrangement, and partly to the fact that it has been already adopted in practice in a well-known commercial establishment, the printing office of the 'Times' newspaper in London.

The vertical arrangement of the carbons is retained in this regulator (Plate III., Fig. 8); but each carbon is, as it were, split in two lengthwise, and the halves placed relatively to each other in the form of a V, approaching each other only at the point of illumination. Any one of the carbons, it may be urged, may thus be removed for renewal without extinguishing or interrupting the light. Each of the carbons passes through a holder, with a small guiding wheel, at a point about two inches from the luminous point, whatever the entire length of the carbon. As it is at this point that the electric current enters the carbon, the total resistance the former experiences in its passage to the luminous point is due to the intervening two inches of carbon only, irrespective of the entire length of the latter. This resistance is therefore uniform throughout the entire time of combustion. The last advantage is likewise shared, as already seen, by the "horizontal" regulator of M. Lontin, where each carbon is gripped at a short distance from the luminous point, and independent of the length of the carbon.

The gradual progression of the carbons towards the luminous point, as required by the rate of combustion, is effected solely by the intervention of gravity. A small dead weight works up and down on the two vertical guide-rods, from which the jaws carrying the carbons are made to project. The weight is connected by thin cords, working over small pulleys, with the end of each of the four carbons, and tends constantly to urge them towards the luminous point, the actual vertical distance by which the upper and lower pair of carbons shall be separated, being adjusted to the required length of the voltaic arc by means of a screw, fixed on the hinder part of the jaw which carries each pair of carbons, raising or depressing it vertically. This adjustment can of course be made, whenever required, during illumination, according to the strength of the electric current.

In almost all forms of regulators it has been found necessary to introduce some automatic arrangement, generally by means of an electro-magnet, or a coil placed in the bottom of the apparatus, to compensate any irregularities in the strength of the electric current, and to separate the carbon points in accordance with it. Nor is an automatic arrangement of this nature wanting in the Rapieff regulator, to cause the necessary closing up of the carbons to produce lighting. The two thin flat bars of an electro-magnet, placed horizontally over one another, are able, by reason of the play or spring in them, to approach each other more or less at one extremity, in keeping with the variations in the current. This movement is communicated by means of a lever to one of the vertical guide-rods carrying the jaw of one pair of carbons, which latter are thus made to correspond to the vertical movements of the electro-magnet.

In the latest forms of this lamp, a considerable modification has been introduced into the regulating part of the apparatus. Instead of one electro-magnet, two are employed; the main current passing through one, while the other, through which is the passage to the carbon points, is placed upon a shunt. This arrangement is somewhat similar to that employed in the Serrin-Lontin regulator; though, it is understood, that in its action the Rapieff lamp has certain distinctive peculiarities not possessed by the other. Latterly, also, the arrangement of the carbons has in certain cases, where required, been modified in the Rapieff lamp. The upper, or positive pair of carbons in the drawing are replaced by a single rod of increased section; and the apparatus is turned upside down for suspension, say from a ceiling. By this means the obstruction downwards to the light rays is reduced to but little more than the single carbon stick; and the shadow cast underneath is diminished in proportion.

The Wallace Lamp.—The drawing (Plate III., Fig. 7) shows the improved and more compact form in which this regulator is made by Ladd. Its designer, Mr. Wallace, was also one of the inventors of the Wallace-Farmer dynamo machine; which has been already described.

This lamp varies from all which have been so far named by the use of flat plates of carbon, generally from $\frac{3}{16}$ to $\frac{1}{4}$ of an inch in thickness, according to the nature of the current and the position of each plate as an electrode. On the top of the brass frame is fixed vertically, enclosed in a round brass box, an annular electro-magnet with a flat circular armature plate placed horizontally beneath it. The rod of the upper carbon-holder passes upwards through both the electro-magnet and the armature. As the hole in the armature plate is only just large enough, when in a horizontal position, to allow the rod of the carbon-holder to pass freely through, a very slight tilting of the former, when attracted by the magnet, causes it to grip the rod, and carry it upwards with it. As soon, however, as the magnet releases its hold by the cessation or the weakening of the current, a spiral spring wound upon the rod forces it down again; and with it, for a certain distance, the armature also. The amount of play allowed to the carbon-holder may be regulated to suit the required voltaic arc, by means of a stud and screw attached to the underside of the armature. The upper or movable carbon is the positive electrode, the current passing to it through the electro-magnet; while from the lower carbon the current is carried through the frame to the other contact-screw.

This lamp, so far, works only with the Wallace-Farmer machine, a continuous-current one; but it is stated to be able to be modified to suit an alternating current also. The carbons, being of large area, may be made to last for a considerable time; for fifty hours, or even more, it is said. Their size, however, renders it extremely difficult to obtain them of uniform granular texture throughout, a quality which it is hard to obtain even with the ordinary carbon in sticks. This want of homogeneity in the composition of the carbons adds still more to the oscillatory nature of the light, which is allowed unrestrained to travel to and fro along the carbon edges.

Lamps working by Incandescence.—All the forms of regulators, which have so far been described, develop their light by means of the voltaic arc; that is, where a large amount of electricity is absorbed, owing to the resistance offered by the large gap or interval between the electrodes, and where consequently a light of considerable intensity is produced. If, however, it is desired to obtain a light of much reduced power, and an electric current of a lesser tension is made use of, it is found that when the voltaic arc becomes so much reduced in length as to be almost, if not entirely, suppressed, another effect is produced; namely, that a portion of the positive electrode (the one by which the current arrives) becomes incandescent for a short distance backwards from the point.

Two forms of lamp, working in this manner and using carbon for their electrodes, are known in France and in this country. They are due to M. Reynier and to Mr. Werdermann respectively. In them, it must be remembered, there is a distinct break or disconnection between the two electrodes, and that it is not one single body which is rendered incandescent; though lamps on this principle, and making use of platinum, or iridium, or an alloy of both, may (if report speaks truly) be used before long in actual practice.

The Reynier Lamp (Plate III., Fig. 5).—A very thin rod of carbon, only about one-sixteenth of an inch in thickness, and forming the positive electrode, is placed vertically above and impinging upon the outside edge of the negative electrode, which is a disc of carbon, about one inch in diameter and one quarter of the same in thickness, and fixed vertically. This disc is free to rotate, and so to aid the slightly outward thrust which the point of the carbon rod exerts upon the edge of the disc, by the aid of a small inclined and hinged arm pressing upon the rod from behind; the object being to throw off from the disc any accumulation of carbon ash, which might otherwise cause an interruption in the flow of the current. The frame carrying the carbon disc is hinged just behind the standard, within which the shaft of the carbon-rod holder works; its slight pivoting action also aids in the above object. The carbon rod passes, near to its point, through a silver-lined collar, and it is gripped at the top in the socket of the projecting arm of an upright shaft, both of brass; this last works up and down, guided by two pairs of small wheels, within the hollow standard, which also carries the frame of the carbon disc. The weight of this metal shaft keeps the carbon-rod point constantly pressed against the carbon disc.

The electric current passes up through the body of the lamp, the standard, and metal carbon-holder, to the carbon rod; and from the carbon disc it travels through its frame, insulated from the standard, and down a separate wire at the back to its contact screw, both of which are also insulated from the rest of the lamp.

Experiments in Paris would seem to show, that from a Gramme machine, of the single-light type, ten of these lamps were supplied at one time; each affording a light of about fifty candles. This was emitted from the incandescent part of the carbon rod, extending upwards from the point nearly to the small silver-lined collar.

The Werdermann Lamp (Plate III., Fig. 6).—Here, as in the preceding form of lamp, a carbon rod, of about one-eighth of an inch in thickness, is made use of for the positive electrode; and a disc-like mass of carbon forms the negative electrode, though of somewhat larger dimensions than in the Reynier. The carbon rod, however, is placed below the disc; the under side of which is made somewhat convex, to counteract the consumption, or rather the pitting, caused by the flame from the point of the carbon rod. No arrangement is considered necessary to carry away the refuse ash, which simply is allowed to fall off the under side of the carbon disc.

The only regulating arrangement provided, is that for the upward travel of the carbon rod, according to the rate of consumption. This is effected in a way somewhat similar to that of a candle in a carriage lamp. The bottom of the carbon rod rests upon a small piston, which is pressed upward, either by a spring, or more generally by a counterweight, annular in form and working in the space outside the tube which contains the carbon rod and its supporting piston. The cords, by which hangs the counterweight, pass over two small pulleys at the top of the outer encasing tube, and they have their other ends fastened to the bottom of the piston, which propels the carbon rod. The pulley-frame forms a sort of socket or base, upon which is placed a hollow copper tube, tapered to a point at the top and split in two; so that it can be gradually tightened by means of a spring collar and screw, which hold the halves together; the object being to relieve the carbon rod of a portion of the upward force of the counterweight; so that, while still leaving an amount of pressure upon the carbon rod, it is able to obey the downward repelling tendency of any small voltaic arc which may be formed of sufficient resistance to exert the required amount of opposing force to the counterweight.

The electric current has access to the carbon rod near to its upper end by means of the framework and the split copper tube; the distance traversed by the current, and consequently the resistance offered, being always the same irrespective of the length of the carbon rod; while from the negative electrode the current passes away down the insulated standard, which carries the spring ring and screw that clip the carbon disc and support it.

The extremely simple arrangement of this lamp is striking; if, in actual practice, it be found to suffice.

Experiments have shown that the output of a Gramme (double coil) electro-plating machine was sufficient to support ten of these lamps on one circuit at the same time; the illuminating power of each light being *stated* to be rather more than that of eighty standard candles.

Candles.—This term, as already stated, is here applied to those forms of lamps where the carbons are fixed in position, so far as to dispense with any regulating apparatus to control the travel required by the consumption of the carbons. In some, however, of the forms about to be referred to, a slight amount of movement is provided for. With this class of burner, if the two carbon sticks are made of similar section, as it is almost always the case, an alternating-direction current must be made use of, so as to ensure an equal rate of combustion for both carbons.

The Jablochkoff Candle.—A "candle" (Plate III., Fig. 2) consists of two cylindrical sticks of the carbon ordinarily in use for electric lighting, each about $\frac{3}{16}$ inch in diameter and 10 inches long; they are placed vertically alongside of one another, with a space of $\frac{3}{16}$ inch between them. This interval is filled in with plaster of Paris (sulphate of lime); though at first kaolin, or china clay, was used for the purpose.

M. Jablochkoff's idea in this arrangement was evidently a desire to dispense with the delicate mechanism in use in the ordinary regulator (such as in the Serrin lamp), in order to keep the carbon points sufficiently near to one another to allow of the voltaic arc being properly formed between them. This he effects by placing the two carbons alongside of one another; but with an insulating substance between them, and at a distance sufficient to prevent the electric spark passing directly from one carbon to the other.

Before lighting, there is laid horizontally on the top of the candle across the plaster a small bit of carbon, to lead the electric current from one carbon to the other. During combustion this communication is kept up by the gradual fusion of the insulating layer, as the carbons burn downwards. This necessarily involves a considerable loss of electric force, probably quite 30 per cent.; which, with the ordinary arrangement of the carbon points opposite to one another, would all be utilized in augmenting the intensity of the voltaic arc. Should the light, however, through any irregularity in the current, be extinguished after it has been lit, there is no relighting the candle without replacing a fresh piece of carbon on the top surface.*

A very serious objection to these candles is the shortness of their duration, only one hour and a half on an average. It is true that the bottom plate of the lamp carries usually a supply of four candles (which number may be increased), and that these are arranged so that the current may be deviated from the burnt candle to a fresh one. Although an automatic arrangement to effect this object has, it is said, been devised, yet so far in the street lighting in Paris, and elsewhere, the change has been effected by hand.

The quality and steadiness of the light produced from the candles leaves much to be desired. For, besides the irregularities in the flame introduced by the want of uniformity in the composition of the carbons (which it is the present object of their manufacturers to minimize), there are added those consequent upon the volatilization of the insulating layer of plaster of Paris. This last, moreover, from its chemical composition, introduces from time to time, into the otherwise pure flame, rushes of a red colour, which differ much in intensity and duration. The amount of unsteadiness from these several causes varies, however, very much in different places.

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* A modification has lately been introduced, by which, it is said, the difficulty of relighting is overcome.

The De Meritens Candle (Plate III., Fig. 3).—Exteriorly at first glance this presents much similarity to the preceding, but its construction and general principle differ considerably from it.

In the De Meritens the two carbon pencils are separated wider apart, and a third rod of carbon, perhaps somewhat thinner than either, is placed between them; but separated from each by a space left open and unfilled by any insulating substance. This central carbon is insulated entirely from the other two, and is not in direct communication with the electric current, which passes up and down the outer carbons. The effect of this central carbon is to divide the otherwise long voltaic arc into two of more moderate dimensions, by means of the two poles of opposite nature induced in the central carbon; and which M. De Meritens terms "a condenser of neutral electricity." The result of this arrangement is that a steadier flame (it would seem) is produced, and one somewhat augmented in luminous intensity, than with the Jablochkoff; the latter fact being probably due to the portion of the electric current, absorbed in the last-named form in fusing the insulating layer of plaster of Paris, being available for the production of light. The more moderate dimensions of the voltaic arc, in its double form, in the De Meritens, should not necessitate an electric current of so high a tension, as is notably the case with the Jablochkoff.

There remains, however, with the De Meritens, as with the Jablochkoff, the great objection that these candles are not self-lighting at any time without the aid, in the first instance, of a small bit of carbon to lead the current across the permanent gap which exists between one electrode and the other. In the two following forms of candle, the Wilde and the Rapieff, this defect is remedied by the addition of a small electro-magnet and armature in the socket of each candle; whereby is effected the movement of approach and of separation necessary for lighting.

The Wilde Candle.—Externally it is very similar to the Jablochkoff, as to dimensions of carbon sticks, and in the space between them; which, however, is left free of any insulating material. The space between the carbon rods, each of which is placed in a separate and detached socket, is normally parallel from top to bottom. The exact dimension, at the point where combustion is occurring, between the rods is, as already said, regulated by the electro-magnet in the socket of each candle. To the pivot of the armature plate of this magnet is attached the socket of one of the carbon rods; and hence the rod is made to work in unison with the magnet.

The Rapieff Candle differs in principle but little from the preceding (or *vice versâ*). Externally in appearance it is more of a tripod; as two sticks are sometimes used for the positive electrode, when designed for continuous-direction currents. The negative electrode is, in some cases, kept pressed forward towards the positive one by a spring according to the rate of combustion; the exact distance being controlled by the electro-magnet in the base of the apparatus.

CHAPTER IV.

CARBONS—CONDUCTING WIRES.

Carbons.—The composition of the substance which forms the electrodes or terminals at either extremity of the gap in the electric circuit, between which the voltaic arc is formed, always has been, and will continue to be, a most important point in the practical application of electric lighting. Indeed, at the present time, it seems to be very generally admitted that upon the discovery of some indestructible substance whereof to form the electrodes, so as to supersede the use of carbons, which rapidly consume, depends in a great degree the extension of electric lighting beyond its present restricted limits.

The difficulty which attends the question may be judged of when it is considered that the temperature of the electric flame is, probably, considerably over 3000° Fahr.; and that most substances, such as quartz, diamond, and plumbago, were found by Sir Humphrey Davy to be fusible readily in the electric flame produced between the carbon points. Although this last-named substance was found by him to be of a sufficiently refractory nature for his purpose; yet we now, owing to its wasting away, are compelled to seek for a still more refractory substance, in order to meet the requirements of actual application of electric lighting on an extended scale. As carbon is at present the only substance, practically, which is used for the electrode points, the following brief remarks will refer to it solely.

Sir Humphrey Davy seems to have made use of wood charcoal for his carbon points. Foucault, later on, in his lamps, commenced using graphite, or mineral carbon deposited on the sides of gas retorts. This material has been found to be so much more suitable than the vegetable charcoal that it now almost universally forms the basis of the carbon used for electrodes.

For some time the carbon sticks were merely cut out of the graphite as naturally deposited; but, as the granular texture of that substance was found to be somewhat irregular, and likewise to contain sources of impurity, all of which might be at least partially got rid of, attempts were made to eliminate them; the more so, that these imperfections were the cause of considerable flickerings and want of steadiness in the electric light produced. Various methods, involving different processes, have been adopted to effect this improvement. The chief ingredients in these artificial compressed carbons, as now made, seem, however, to be graphite ground up into a fine powder and carefully washed and purified, with the addition of a glutinous syrup formed of molasses or other similar matter, to render the particles of carbon sufficiently adhesive; and also, perhaps, a small proportion of lampblack or other sooty substance. This mass, after being pressed and passed through moulds, is subjected to a series of careful dryings.

Many attempts have been made to increase and to develop certain qualities in the carbons produced, by the addition of certain substances; potash, soda, lime, magnesium, strontium, iron, antimony, &c., being found to add, in different degrees, to the amount of light given out; while boric acid and other matters increased somewhat the duration of the carbons during combustion. The addition of these substances is, however, now generally discontinued, it is understood. Again, divers products of gas tar, deposited by distillation in retorts, have also been used, especially by Gaudoin, and with apparently good results. Metallizing exteriorly the finished carbon stick, with a deposited layer of copper, or of nickel (as advocated by Reynier), has also been tried. It is stated, however, that during the consumption of the carbon this metallic layer gradually keeps forming itself into a series of globules at the carbon point, and then dropping off.

Most of these various expedients have, however, it is believed, been gradually discontinued; and the manufacture of these artificial carbons, it is understood, consists almost entirely of the powdered graphite, with the one or two necessary additions first referred to. The carbons of Carré, of Gaudoin, and of Archereau, are the best known of the French manufactures; while in this country Siemens, who deposits an exterior layer of copper, is also very successful in their manufacture.

These artificial carbons are made cylindrical in form, and in diameter varying from about $\frac{1}{16}$ of an inch up to 1 inch nearly (for lighthouse illumination). Some special forms have a hollow core through their length. The dimensions in most general use for ordinary illumination are, with regulators such as those of Serrin, of Siemens, and of Lontin, from $\frac{3}{8}$ to $\frac{1}{2}$ inch in diameter; while with the Rapieff, the carbons are about $\frac{3}{16}$ inch thick; the Werdermann taking about $\frac{1}{8}$ and the Reynier as low as $\frac{1}{16}$ inch respectively. These carbon rods are generally made from 12 to 20 inches long, for facilities in carriage; but they can be had, if required, up to 3 feet, or even more, in length. The Wallace and other plate lamps are still dependent upon naturally-deposited and cut carbons; though it is anticipated that before long artificial compressed carbons will be made to suit them.

CONDUCTING WIRES.—These are generally made of copper wire, or of flat ribbons of this metal. For electric-light machines a bundle of wires of small section (No. 16, B. W. G., or 1·5 mm., diameter), bound up together and surrounded by an insulating material, such as hemp or gutta-percha, or both, seems to be preferred; while for electro-plating machines, or for those where the current is more abundant in quantity but of a lesser tensional power, a single ribbon of copper appears to be more suitable. Two qualities of copper are in use for conducting wires; one of what is termed ordinary quality, and the other of higher conducting power, by about 30 per cent. It is stated by some, as the result of experiments, that if the wires of a cable composed of the ordinary quality be severally twisted, their conducting quality is increased so as to equal that of the superior kind of wire.

The exact cross section of the conducting wire, or cable, to be used must vary in each particular case, with the internal resistance of the electric machine employed; with the nature and quality of the current produced, whether of high or low tension, and whether continuous or alternate in direction; and, principally, with the distance or length of each circuit. The degree of tension of the current again varies, not merely with the number of lights upon each circuit, higher in proportion as the number increases, (i. e. as the gaps become more numerous), but also with the nature of the lamp or burner employed; the Jablochkoff candle requiring a higher tension than do regulators of the Serrin type; while in the Werdermann, where the voltaic arc is small and incandescence prevails, a very low degree of tension suffices.

The following are some of the dimensions of cables in actual use by certain makers. The wire used in all of them, except the example of the "Gramme," being of about the same diameter No. 16, B. W. G.

	Gramme.				Siemens.				Lontin.				Jablochkoff.
Number of wires in cable	8	16	25	35*	7	14	19	49	12	15	20	20	7
Total length of circuit, in yards ..	180	330	500	750	90	180	240	400	220	330	440	660	For all lengths up to 1300.
Description of machine	Single light, 6000 candles (nominal). Type "A." Continuous currents.				Single light, 6000 candles (nominal). Type "B." Continuous currents.				12 lights, 500 candles each =6000 candles. Alternating currents.				16 lights, 300 candles each =4800 candles. Alternating currents.
	Northern of France Ry., Paris.				London, and elsewhere.				Western of France Ry., Paris.				Avenue de l'Opéra, Paris.

Notwithstanding the many and varying elements, which must lead to very different sections of cable being used in each particular case, attention cannot fail to be drawn to the discrepancy in practice in the cables provided for the Lontin lamps, and for those which serve the Jablochkoff candles; the circumstances in each case, as to power of electric machines used, as to the number of lights provided, and as to the nature of the current made use of, being not very dissimilar.

The question of conducting wires and cables (and of resistance generally) is one that may with prôfit be studied, and much valuable information obtained therefrom; especially as to the loss of current resulting from distance in the use of alternating-direction currents.

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* Single wire only, instead of a cable, is used in each case under this head. But, for better comparison, the figures given represent the number of "No. 16" wires which make up an equal section.

CHAPTER V.

MOTIVE POWER.

The immense, nay paramount, importance which this portion of the question bears to the practical application of electric lighting can be imagined, when one remembers that the very production of the electric light (for purposes of illumination, at least) depends upon the conversion of a certain amount of mechanical duty into electrical force. That converted duty, expressed in horse-power, represents so much money expended; and the result is afforded in the amount of light supplied for effective illumination, relatively to the cost at which it could be provided from any other illuminating source.

Mechanical duty being, therefore, of primary necessity in electric lighting, it is of equal importance to seek to obtain it under conditions the most favourable to economy. For to provide this mechanical duty must ever be the chief working expense attending its production; since that of the carbons, or combustible electrodes, may be diminished most considerably by the substitution of some indestructible substance. But a mechanical motor must always be provided, as long as the present mode of creating the electric current is retained. The motors which are generally available for this mechanical purpose are steam, gas, and water; and in some particular cases air, whether compressed, or in a heated state.

It is hardly possible, within the limits of these remarks, to enter at any length into the different merits of these several motors. But it may probably be found that water power, especially in the form of a turbine, would afford the most regularity; that the gas engine will be found the most convenient, where the horse-power required is not great (up to 10 horse-power); and that the steam engine will be the one in most cases ready to hand in manufactories, &c., already possessing steam power. But in the last-named case it should be strongly borne in mind that a *special* engine should be devoted to the use of the electric light; and that this duty should not be imposed upon an engine which has other duties to perform and other machinery to drive; these duties being often of an intermittent character, apart from the irregularities in the running, which occur from temporary variations in load arising during the performance of its ordinary duties.

The one pre-eminent requirement, which is exacted from all motors, is that of *extreme regularity* of movement, not merely during each revolution, but also during successive revolutions. To counteract any irregularities on this head, the ordinary precautions of the double cylinder, and of one, or of two heavy flywheels, and of a good sensitive governor can be introduced. But there are also sudden and other irregularities and heavy strains which are thrown upon the motor power from the electric machine itself, especially at the moment of illumination, all of which the motor power is expected to overcome, and that almost immediately; otherwise very considerable variations and fluctuations in the electric light are the result. For this purpose a governor with automatic expansion gear acting upon the cut-off valve would appear to offer one palliative at least.

The Steam Engine.—In the steam engine any considerable variations in the pressure of the steam, dependant in great measure upon the stoker, and therefore preventable by his diligence, are immediately reproduced in the work done by the engine. They are made sensible in the alterations in the number of revolutions of the flywheel; to be again reproduced in an intensified form in the speed of the electric machine. The greater the difference in the relative speeds of the engine and in the electric machine, the more will these variations be magnified and made apparent. It is a very serious disadvantage, at least where hand stoking is necessary, that the regularity and steadiness of an otherwise perfectly satisfactory electric light should be liable to be discredited by, and placed in constant dependance upon, the careful supervision or otherwise of an attendant of a subordinate character.

The type of steam engine which seems to be most suitable, at present at least, to the requirements of electric lighting, is the agricultural one, either portable or semi-portable. The performance, capabilities, &c., of this class of engine, of about 8 horse-power nominal, have been the subject of a series of very exhaustive trials, made under the auspices of the Royal Agricultural Society at its Cardiff meeting in 1872; and also on previous occasions. Most of the best-known makers were there represented, each with his own distinctive machine. The results of those careful trials showed on an average that (for a specially prepared occasion) from 12 to 18 indicated horse-power was the most economical amount of work that could be developed by an engine of 8 horse-power (nominal), with a consumption of 4 lbs. of picked coal per indicated horse-power per hour. Under the ordinary conditions of practical work it is supposed that with the average quality of coal, 6 lbs. would probably represent the mean hourly consumption.

If the varying cost of coal at different places be taken into consideration, and also that in the rate of wages to attendants, 1*d.* to 2*d.* may be taken as a very rough approximation of the actual average hourly cost per indicated horse-power of this class of engines — not that 8 horse-power nominal must be taken as their limit for electric light purposes. If used for this object, it is probable that these figures will be quite maintained; as special care in the attendance is requisite.

The Gas Engine.—By this is meant the one using ordinary illuminating coal gas. The type of this machine, rapidly coming into use, which seems to be best known in this country, is the Otto gas engine. In this motor there does not exist the disadvantage to which the steam engine is liable, of a variable pressure being possible in the supply, and depending upon the vigilance of an attendant. For with the gas engine, once the suitable admixture of gas and of atmospheric air is arranged, the same proportion will always continue in the supply. Besides, this description of motor is cleanly, and requires, when once started, comparatively but little attendance. A peculiarity of the gas engine is the mode in which it adapts itself automatically to the exact amount of work demanded of it. It may not be out of place, as the gas engine is a comparatively new form of motor, and one which seems well adapted where steam is not already available to electric light purposes, to mention here a few of the features of this machine.

The sizes made at present are of 1, 2, 3½, 8, and 16 horse-power nominal, but capable each of developing about fifty per cent. more power. The most suitable size, as a motor for electric light machines, is in general the 8 horse-power one, capable of developing up to twelve horses; it is the size referred to in the following remarks. The normal number of revolutions of the flywheel per minute, for all sizes of engine, is 160; but in practice it is somewhat less, about 155. By reducing the weight upon the governor this number can still further be reduced to about 135, or even less.

The maximum power of the engine is developed, when one explosion of the gas mixture takes place for each pair of revolutions of the flywheel; that is, 80 explosions when at the rate of 160 revolutions per minute. It is, however, in the exact adaptation of the number of explosions to the work required to be done that lies the automatically variable property of these machines, which has been just referred to. For, while the suitable admixture of the gas once arranged remains without change, as also do the number of revolutions of the flywheel and consequently the speed of the electric machine, the number of gas explosions per minute augments or diminishes automatically with the amount of work the machine encounters. Or, in other words, the force of each explosion expends itself quickly or slowly, in proportion to the resistance which it has to overcome. Thus, when the engine is running light, and has only its own friction to overcome, the number of explosions may be say 15 to 20 per minute; but as soon as the electric machine is connected, the number increases to perhaps 30, 50, or even much more, without affecting notably the revolutions of either the engine or the electric machine. No doubt the momentum of the flywheel has much to do with this steadiness in the speed of the engine, notwithstanding this irregularity in the supply of the power. In view of those sudden and considerable additions of strain, which electric machines are liable to cause, especially when the light is first started, this instantaneous and automatic adaptation of the supply of the driving power to the resistance to be overcome, answering to the automatic expansion of the cut-off valve of the steam-engine, appears to be a very valuable quality in overcoming and immediately counterbalancing these irregularities. The hourly consumption of gas of these Otto engines, with the average admixture and irrespective of the size, is stated to be about 23 cubic feet of gas per indicated horse-power. This, at the average price of coal gas in England, say 4*s.* per thousand cubic feet, would be about 1⅛*d.* per hour.

One point has already been adverted to, as of importance in diminishing the effect upon the electric machine of any irregularity in the running of the engine motor. It is to reduce as much as possible the difference in the normal speeds of the two. On this point the gas engine, at present, has some advantage; but signs are not wanting to indicate that the speed of the type of steam engine selected for this purpose, is being increased so as to diminish the disproportion. For, while the ordinary speed of the agricultural type of engine, as hitherto used, has been generally from 70 to 90 revolutions per minute, the very fine 20 horse-power engine of this class, lent by Ransomes, Simms, and Head, to work temporarily the Gramme machines supplying the Jablochkoff lights on the Thames Embankment, runs nominally at 140 revolutions per minute.

Water Power, though perhaps more regular in working than either of the preceding, and more economical, yet is not often to be found available in sufficient abundance where electric lighting is required; and besides, it is probable that it would in most cases, except with turbines, necessitate the use of considerable multiplying gear between the water motor and the electric machine. At Craigside, in Northumberland, the seat of Sir William Armstrong, where the force of a waterfall is utilized to drive a Siemens electric machine, it is done by means of a turbine. The current is made use of, it is said, to light up the picture gallery.

Caloric, or Hot-air, Engines, made by Brown, of New York, of 10 horse-power nominal, are used to drive the Siemens electric machines which furnish the light at the Lizard Lighthouse. The peculiarly isolated situation led to the selection of this form of motor, and the expectations which did so have been fully realized.

Several other forms of motor may no doubt be found occasionally suitable for driving electric-light machines; but in each individual case a careful consideration of its particular circumstances must precede the selection of the motive power most suited to it.

Motive Power required.—To a general inquirer, as to the probable total power required to drive any particular electric machine, with a view to providing an effective motor, it must be somewhat embarrassing to find the manner in which the answer is given; especially by the makers of those machines. So much "actual horse-power required," or so much "horse-power absorbed" by the machine, is the almost universal answer. Setting aside the very greatly understated amounts given in many instances, what then is the meaning of the above statements? The above expressions are generally interpreted as meaning the average additional indicated horse-power required to drive the electric machine, over and above that which is absorbed by the friction of the motor itself; and moreover, this additional power is correct only when the electric machine has settled down to its work, and has overcome that considerable extra strain, amounting perhaps to 50 per cent., which always occurs at first lighting, and which is apt to recur at times, though in a mitigated form. The "actual" or "absorbed" power of an electric machine is therefore only a *net* amount; while the *gross* power includes also the friction of the motor and the excess claimed by exceptional strains.

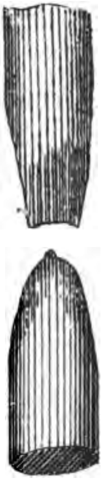
It seems hardly fair that the particular electric machine in question should be debited with the loss due to the inertia of the motor used, or to the sudden strains, some of which have nothing to do with itself, but may arise from the lamp or the conducting wire. Still it is the gross amount which the intending purchaser wants to be made acquainted with, and not merely the net absorption by the electric machine. Where a large amount of power is already provided, or even where the capacity of the machine will be considerable, say about 30 horse-power, the difference between the gross and the net powers will not be of so very much importance; as the elastic limit between the nominal and the indicated power of the motor will probably readily cover it. But, as is generally the case, at present at least, the power "absorbed" is very small, stated perhaps at 2, 3, or 4 horse-power; and to provide a motor with only about that nominal power, or even somewhat in excess, would be most probably insufficient, and misleading to the intending purchaser.

To endeavour to afford some answer, with regard at least to these smaller sized electric machines and their requirements, the Table on p. 100 has been prepared from cases in actual practice, and arrived at with what appeared to be suitable precautions as to accuracy of measurement. The data must, however, be taken with caution and with reserve; merely as an approximation towards a more accurate knowledge of the amount of power required by different electric machines. It must also be borne in mind that electric machines of the same construction and like nominal output may develop a different amount of resistance from one another; that the motive power and consequently the loss by friction will probably vary in each case, and that the nature and extent of gearing and other local circumstances will again probably introduce further elements of difference. And all this without entering into the question of lengths of conducting wires, or of resistances in the circuits. An inspection of the Table, p. 100, where several examples of the same electric machine occur, shows how very materially these matters affect the results.

M I

Plate IV.

Diffus



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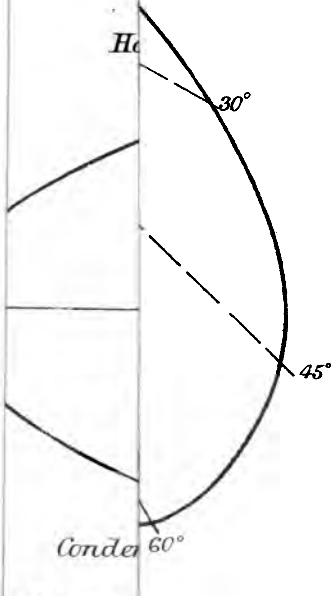

Conde

500 Candle
250
300

V. Si

kell, Photo. Lith. London

CHAPTER VI.

LUMINOUS INTENSITY.

THE commercial success of any particular application of electric lighting will depend almost entirely upon the amount of effective illumination that is produced for a given expenditure, in the form of motor power and other working expenses. A careful examination of the arrangement which will, in each particular case in question, afford the maximum of *effective* light, is therefore of primary importance. The measurement of the amount of the light given off, together with any peculiarities it may possess as to predominating direction, colour, &c., form naturally prominent points in this inquiry. Two causes especially single themselves out as being of influence upon the light: the nature of the electric current producing it, and the particular lamp or burner employed. The last, besides indicating the intensity of that current, may also impart certain distinctive peculiarities of its own.

With "continuous" currents, that is, those which are always proceeding in one direction, it has long been noticed that, if the two carbon rods serving as electrodes are placed vertically in a line over one another, the positive one—the one from which the current passes—is always consumed much more rapidly than is the negative one; also that its extremity, losing its tapered point, becomes blunt, flat-headed, and inclined to hollow out in the centre, while the negative carbon retains its cone-like shape. It was supposed also, that this crater-like form which the positive carbon-point assumed, acted as a reflector; from which the light (the majority of which is supposed to be emitted from the positive electrode) was projected either upwards or downwards, according as this positive carbon was placed below or above — the latter being generally deemed the more advantageous arrangement. A series of careful photometric measurements, carried out by different observers in France, have fully borne out these suppositions. Perhaps the most complete and most extended are those taken under the direction of Messrs. Sauter, Lemonnier and Co., of Paris. In Fig. 1 of Plate IV. is shown an average curve of luminous intensities, as resulting from those observations, and taken in the vertical plane passing through the luminous point. It represents the output of a single-light Gramme electric machine of the "A" type, as emitted from a Serrin lamp; the sketch alongside showing the carbon points (full size) in the form they usually assume. This curve shows very clearly how small an amount of light is allowed to pass above the horizontal line between the carbon points; and that the maximum of light is shed downwards at an angle of between 50° and 60° below that line, and with an increase of about fourfold. The general form of this luminous curve of intensities has been borne out by the careful experiments recently made by the Northern of France Railway at their goods station at La Chapelle, with the same kind of machine — the single-light Gramme, "A" type. The actual amounts of the several intensities were, however, found to be much less in the latter case, of actual practical application, (see Table, p. 100) than in the former, where the values arrived at appear excessive.

Reference has already been made to a series of careful and valuable comparative experiments, carried out at the South Foreland lighthouse in 1876–77, for the corporation of the Trinity House, by their engineer, Mr. James N. Douglass, as to the relative value for lighthouse illumination of certain magneto-electric and also dynamo-electric machines. While operating with the continuous-current single-light machines of dynamo construction, the Siemens and the Gramme, he found that, when the carbons were so placed vertically over one another that the axes of both were in the same line, their extremities were consumed in the manner already described, and with a blunt head to the positive electrode. If, however, the bottom, or negative, carbon was placed so that its axis coincided with the front of the top carbon, then the upper one, instead of having a blunt-headed extremity, gradually formed its hinder edge into a long tapered point, extending downwards considerably below the tapered top of the lower carbon. The effect of this upon the resultant light was found to be most marked, especially in the horizontal plane of the luminous point. Fig. 2 of Plate IV. shows the relative results in the horizontal plane of the photometric measurements taken with the medium Siemens machine (the "B" size); the upper portion showing the arrangement with the carbons directly over one another, while the lower portion indicates the forward projection of the light due to the advancement of the lower carbon. The great advantage for lighthouse purposes of this forward projection it is needless to dwell upon. Mr. Douglass has called this last arrangement the "condensed beam," while for that in ordinary use he has applied the term of the "diffused beam."

While these observations were being made upon the effect of continuous currents, others were investigating the peculiarities of alternate-direction ones; that is to say, where a series of reversals in direction are constantly taking place. M. Allard, the Inspector-General of French Lighthouses, was studying the distinguishing features of the magneto-machines of the Alliance Company, the only ones in use in the lighthouses in that country, and which give off alternating-direction currents. The result of his investigations is shown in Plate IV., Fig. 3; which represents the curve of intensity, as taken in the vertical plane of the luminous point. This shows how evenly the light is diffused in every direction; the maximum being on the horizontal, and the amount supplied above that line being somewhat less than is the case below it. So slight are the differences at the different angles, that, in order to make them at all perceptible, it has been found necessary to make this figure double in scale of either of the preceding ones. The carbon points alongside show the equable way in which the constant reversals of these currents act upon the consumption of the electrodes.

Another series of very careful experiments were also carried out by M. Lafaurie, of the Western of France Railway, under the direction of M. Mayer, the Engineer-in-chief, upon the lights provided, in a portion of the St. Lazare Terminus at Paris, by one of the Lontin machines, also giving off alternate-direction currents. The upper portion of Fig. 4, also of Plate IV., shows the horizontal measurement of one of six lights provided from a single machine, situate on the arrival side, in the goods yard. The average maximum intensity, taken from a series of observations at each of those periods, is shown; the average of minimum intensity, arrived at in a similarly careful manner, is also marked; together with the mean value of the light, in a dotted line between them. The lower portion of the same figure is an endeavour to portray the periods of oscillation of the wave of light in this particular case, and the duration of each portion. This attempted delineation of the wave of light must, however, be accepted with considerable reserve, as the particular form varies not merely with each application, but from night to night in the same locality, and again even during the same evening. It seems, in fact, to depend greatly upon the regularity of the motor engine, and also upon the quality of the carbon which is being burnt.

The peculiar features of the light emitted by the Jablochkoff candles were meanwhile being carefully studied by M. Allard; not the gentleman of the same name just mentioned as the Inspector-General of Lighthouses, but the Chief Engineer of the Lighting Department of the City of Paris, under the direction of M. Alphand, the Engineer-in-chief. The result of his experiments, carried out upon the lights in the Avenue de l'Opéra, on the site itself, are shown in Fig. 5 of Plate IV.; the right-hand portion representing the luminous intensity curve in the vertical plane, its upper and lower extremities being dotted as indicating the supposed direction it assumes in those parts. The curve indicates the maximum intensity of the naked light, its minimum being also shown nearer to the light, and on the upper side of the horizontal line passing through it. On the lower side of this line are shown the maximum and the minimum intensities due to the interposition of the opal glass globes, which were made use of at that place. The left portion of the figure is devoted to an attempt, as in the preceding case, to delineate the form of the wave of light emitted. Here must be repeated, only even still more emphatically, the caution already given on this head; as these variations in the nature of the light given off from the Jablochkoff candles vary much in different localities. For instance, the same lights, on the Thames Embankment at Charing Cross, in London, present sometimes a duration of the two periods of intensity exactly the reverse of the appearance shown in the figure; due no doubt, in great measure, to the very great care with which everything had there been provided and firmly laid down.

In order to make the different parts of these experiments on the Jablochkoff candles, as well as those of the Lontin light, sufficiently visible, the Figs. 5 and 4, which represent them respectively, are enlarged, so as to be as much as eight times the scale of Figs. 1 and 2 of the same plate. Nevertheless one can hardly fail to be struck by the smallness of the amount of the resultant light of the Jablochkoff candles; even though it is that of only one of sixteen candles supplied from the same machine; the maximum intensity of the naked light being given by M. Allard as somewhat under 300 standard candles, while by the interposition of the globe this was reduced to rather less than 180, being a loss of 40 per cent. The effective amount of light shed on the ground below the lamp was found on an average to be only that of about 90 candles.

The Borough Engineer of Liverpool, in a careful Interim Report on the Electric Light, lately presented to the Council,* estimates the value of the Jablochkoff candle, after careful photometric observation in a horizontal direction, as 453 standard candles from the naked light; diminished to less than 172 candles by the interposition of the globe.

It may not be out of place to make a few general remarks upon the several diagrams shown upon Plate IV.

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* 'Electric Light: Interim Report of the Borough and Water Engineer, December 4, 1878.'

Perhaps the most important, as well as the most interesting lesson, is that contained in Figs. 1 and 3, the luminous outputs respectively of continuous and alternate-current machines, and concentrated in each case into a single light; the amount of light given off, measured horizontally, being about the same in each (it being borne in mind that the scale of Fig. 3 is double that of Fig. 1), as likewise is the engine power absorbed; some excess in both cases, more particularly in the latter point, occurring, however, with the "alternate" current Alliance machine over that of the "continuous" current Gramme.

In the practical illumination of large areas with the electric light, the tendency is each day rendered more manifest, that the best effect is produced by reflected diffusion of the luminous rays, and not by their direct dispersion from the luminous point. Furthermore, it is shown that the luminosity of the point itself, too intense to remain exposed to view, is further apparently increased, at least as far as effective diffusion is concerned, and despite the undoubted loss due to interception by the glass, by the augmented size of a luminous globe. This shield is, however, only needed under the lower portion, to act as a screen for the spectators; while the remaining part of the rays of the voltaic arc are left unrestricted to be freely projected into space when near the horizontal, and those in the upper portion against a reflector; the angle or successive angles, at which these last are allowed to impinge upon the reflector enabling them to be utilized in the direction most needed.

The curves in the plate under consideration, show that from an alternate-current machine more rays are available for downward reflection from the upper portion of the light, than is the case with the continuous-current machine; wherewith to clothe, or extend, the outer edges of the cone of light formed by the rays shedding directly downwards.

Indeed, it may be doubted whether in the latter case there is not a waste of luminous power in the highly concentrated cone of light produced, with its fringes comparatively dark, as against that produced from the alternate current, where the light is more uniform throughout the illuminated cone, thanks to the abundance of reflected rays available on its outer fringes. The Northern of France Railway, at the La Chapelle Station just referred to, found, when lighting up one of the large goods sheds with a continuous current emanating from a single-light Gramme machine and used from a Serrin lamp, that this excessive brightness in the vicinity of the light, while the outer edges of the space illuminated remained dark, was very perceptible. This defect it was sought to remedy, by raising the source of light higher above the ground; thus rendering the illumination somewhat more uniform throughout the entire area.

Another question also suggests itself, as to whether this output would not be more effectively used in practical illumination by being subdivided, as could easily be done with the alternate current, into three or even four light-centres of moderate dimensions, say of 400 or 500 candles each, than could be done with a large central light of 3000 candles; even despite the oft-asserted loss due to the subdivision of the light, and the increased working expenses of augmented engine power and of greater quantity of carbon consumed in proportion to the additional light. The amount of loss entailed by this subdivision is in fact one of the most important points in its bearing upon the economic future of electric lighting. Precise information is much needed on the subject; as some very exaggerated statements, not borne out by facts, have been made as to the quantity of the diminution. The tendency of the daily increasing experience, both in France and in this country, is, however, to show that the loss, both from the increased number of lights and from the extra length of circuits employed, is much less than was anticipated.

Another point, which the consideration of the curves of luminous intensity just referred to forces upon one, is the necessity for the adoption of some uniform *direction* of measurement as the standard of the illuminating power of electrical machines. Measurement upon the horizontal of the luminous point itself has been all but accepted as the standard; not merely because it is the natural position for such measurement, but also that it expresses the output in a form more generally correctly applicable to all kinds of light than does any other; especially since they have been subjected to, and can be interpreted by the results of careful examination, such as those just described. Nevertheless the rigid adoption of some standard direction of measurement is necessary; most especially with continuous-current machines — much mistrust having of late been engendered as to certain of the latter class of machines; the luminous output of which had been, in some cases, placed at so high a figure as to lead those who were acquainted with the peculiar downward-casting property of the light of those machines, to suppose that the output named was in this latter direction; though no statement was made by the makers whereby to infer a departure from the usual horizontal measurement.

So much has been said in this chapter as to the measurement of the light, that a few words on the subject seem to be almost needed.

The legal standard unit of measurement of light in this country is a sperm candle (six to the pound), consuming at the rate of 120 grains (7·77 grammes) per hour; that in France being the Carcel lamp (Bec Carcel), burning colza oil at the rate of 42 grammes (648 grains) per hour;* while in Germany it is a paraffin candle, of which six weigh 500 grammes (1·34 lb.); 7·6 of these candles being equal in luminous intensity to one Bec Carcel.†

M. Leblanc, the Chief Gas Examiner to the Municipality of Paris, gives the value of the French "Bec Carcel" as being equal to 9·5 standard sperm candles; a value which seems to be generally accepted as correct by Mr. Wm. Sugg and other authorities. If these values be taken as correct, one German candle would equal 1·25 English ones.

The measurement of the amount of light emitted from different sources is termed photometry, and the instruments made use of in the operation are called photometers; the kinds most used being the Bunsen, the Rumford, and the Wheatstone. The method employed in all cases is based upon the relative distances from the point at which two sources of light produce an equal illumination: the intensity of each light, according to the well-known optical law, will be directly proportional to the square of its distance from that point.

Bunsen Photometer.—It consists of a small darkened box, placed between the two illuminants to be compared; the light from each being allowed to enter only at the end next to it. The box itself is divided vertically into two compartments by a screen of white paper, with a grease-spot having its centre opaque; the box being moved between the lights until the grease-spot appears neither brighter nor darker than the rest of the paper, from whichever side it is viewed, when the distance to each source of light is

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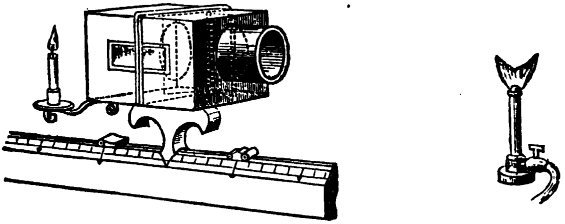
* See 'Proceedings of the Institution of Civil Engineers,' vol. xxviii., "On the Illuminating Power of Coal Gas," by T. N. Kirkham.

† 'Die magnet-und dynamo-elektrischen Maschinen.' Dr. H. Schellen. Köln, 1879.

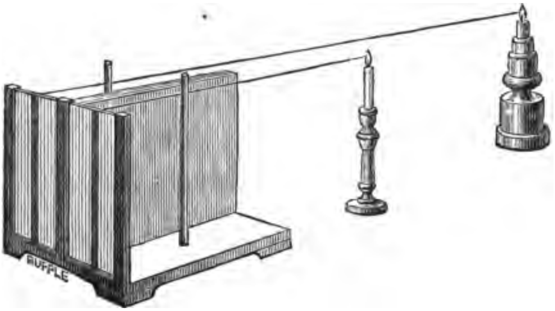


Bunsen Photometer.

noted. To facilitate this comparison two small mirrors are placed vertically at the back of the box, immediately on either side of the screen and at an angle of 60° from it: also a small opening in the front of the box, and extending on either side of the screen, allows of the observations being made. Instead of the grease-spot, the screen is now more generally made of three thicknesses of paper, the middle one opaque, with its centre cut out in the pattern of a star; while the two outside ones, uncut, are of semi-transparent paper.

Several modifications of the Bunsen photometer, which is the system most employed in this country, are in use.

Rumford Photometer. — It is generally constructed of two plates of ground glass, with an opaque division between them and projecting at right angles from them. Two opaque rods are placed vertically, one on either side of the division. The lights are then so arranged as to cast the shadow of a rod on to the glass plate behind it and on the same side of the screen; and the distance of one of the lights is altered until the shadows shall both appear of equal intensity. In some cases but one rod is used, without any division, and the lights placed diagonally, so that the two shadows appear crosswise alongside of each other on the single ground-glass plate.



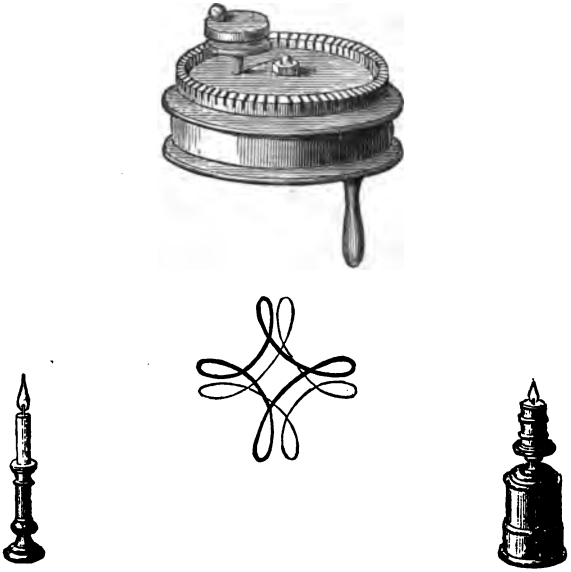
RUMFORD PHOTOMETER.

This form of photometer is much used in France under the name of the Foucault; who introduced a modification of it, and a means of adjusting the divisional screen.

Wheatstone Photometer.—It is based upon the extremely rapid rotation of a silvered-glass ball, by means of multiplying gear from a winch-handle underneath. A double motion is imparted to the ball: that of rotation on the axis of the small disc on which it is placed, which pinion is at the same time carried round the rack which forms the outer rim of the circular case which encloses the mechanism. The combination of these motions causes the ball to move in a looped curve. If the instrument be placed between the lights, and the ball rapidly rotated, the result, as is shown in the latter part of the figure, is that the illumination from each light causes a bright line in the form of a loop; each line differing in brightness in proportion to the distance from its source of light.

This instrument, quite a pocket one, is used in this country more than elsewhere.

The principle upon which it is based is the comparison of the two lights by the brightness of the lines in which their respective intensities are represented; in the Bunsen photometer it is more in a mass of light that the two illuminations are compared; while in the Rumford it is by relative darkness of the shadows cast by each that the intensities of the lights are compared. Several other photometers, some acting chemically upon sensitive paper, are also in use.



Wheatstone Photometer.

In the measurement of an electric light by means of comparison with another standard light, whether it be gas or oil, two things are specially noticed, and each forms a difficulty for the photometrist.

They are, the very considerable and somewhat periodic oscillations in the intensity of the electric light, and the great difference of colour manifested in its illumination when it is brought into close comparison with either of the other two illuminants, gas or oil; the electric light presenting a much bluer, colder appearance than either of the others, which have a warm yellow hue in comparison. This peculiarity in the electric light is said to be accounted for by its spectrum, in which the heat rays are small in proportion to the chemical ones.

Considerable practice and extreme care in the observations, which should be several times repeated, seem to be the best antidote to overcome these difficulties. Several remedies have, however, been tried to overcome the difference between the colours of the lights; amongst others, by the interposition of glass screens of divers colours between the observer and the photometer screen.

Some difference of opinion has been expressed as to the intensity of the standard of actual comparison with the electric light, seeing how much more powerful this is than the flames which have hitherto ordinarily formed the subject of photometric measurement.

It is well known, that in the manufacture of the standard sperm candle, it is almost impossible to make two of them precisely equal in all respects; and that differences exist in practice which, though small in themselves, become of considerable importance by being magnified many times in the relatively large ratio which the electric light bears to them. It seems, therefore, only a prudent precaution to make use of a somewhat high multiple of the standard candle, thereby ensuring its more accurate mean value, as the actual light to be compared with the electric flame.

Mr. Douglass, in the South Foreland experiments, already referred to, made use of the Trinity 6-wick oil lamp, of 722 standard candles intensity, as the means of comparison with the powerful electric lights he there had to deal with. Mr. T. W. Keates, the Superintending Gas Examiner for the Metropolis, in his recent measurements, for the Metropolitan Board of Works, of the light of the Jablochkoff candles on the Thames Embankment, made use of his sperm-oil lamp, equalling 16 candles. Again, the French observers invariably make use of their Bec Carcel, of 9·5 candle power; while, on the contrary, the Committee of the Franklin Institute, in their careful experiments made last year, preferred to use a single standard sperm candle as the medium of comparison; though in their report they somewhat apologetically at the same time admit, that there may be some advantage in a larger comparing medium than that of a single candle.

CHAPTER VII.

APPLICATIONS—ECONOMIC RESULTS.

HAVING in the preceding chapters described some of the machines and lamps in use in electric lighting, and also pointed out a few of the peculiarities of several of the resultant forms of illumination, together with a few words as to the motor power required, in order to afford the mechanical duty which has to be transformed into electric energy, the present chapter will be devoted to the consideration of a few examples of actual electric illumination; and also to an endeavour, through the knowledge gleaned from them, to arrive at some definite information as to the expense of this form of lighting under the conditions of actual practice.

The examples which naturally suggest themselves for selection are those which, from the length of time they have been in operation, and by the care and accuracy that have been observed in the collection of the particulars respecting them, afford some reliable guide. As the application of electricity to lighting purposes has been taken up more eagerly, and has received a greater extension of late years in France than perhaps in any other country, it is but natural that most of the following examples should be taken from applications in that country; especially when it is borne in mind, what attention and minuteness, as to details, that nation is well known to impart to the collection of scientific data.

APPLICATIONS.—The earliest regular commercial use of the electric light, beyond the domain of pure science, was, as has been already stated, to lighthouses.

In March, 1859, after a lengthy and satisfactory experience both at Blackwall and at the South Foreland, the Corporation of the Trinity House first began the regular illumination of the last-named lighthouse by electricity. On February 1st, 1862, this light was transferred to Dungeness, which was thought to be a more suitable place; a view which was not, however, borne out by experience. On December 26th, 1863, the first of the two lighthouses at Cape La Hève, near to Havre, on the French coast, was lit up, its fellow one following not long after; and on February 15th, 1869, that at Cape Grisnez, near to Calais; while on our own shores the electric light shone out on January 11th, 1871, at Souter Point, in Durham; and on January 1st, 1872, the same illuminant was again resumed at the South Foreland.

The machines in use at all these lighthouses are the same in principle; they are magneto-electric, and are based upon those designed by Professor Nollet. Those on the English side being constructed by Holmes, and a lamp also by him is used with them; while those on the French coast have been made by the Alliance Company of Paris, and work with a Serrin lamp. The information as to the former has been kindly supplied by Mr. James N. Douglass, the Engineer to the Corporation of the Trinity House; while as to the latter, M. Allard, Inspecteur-Général des Phares, at Paris, has been good enough to give the details.*

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* See 'Proceedings of the Institution of Civil Engineers,' vol. lvi., "The Electric Light applied to Lighthouse Illumination," by Jas. N. Douglass; also 'Annales des Ponts et Chaussées,' tome xix. 4 series, 1870, "Mémoire sur les Phares électriques de la Hève," M. Quinette de Rochemont. It must be borne in mind, however, that in the following financial details only that portion of the cost necessary

South Foreland and Souter Point Lighthouses.—The plant consists of two of Holmes' magneto-electric machines, used either singly or coupled up together, and driven by steam engines of 10 horse-power nominal. The current given off in each case is alternating in direction, and serves to feed a Holmes lamp with square carbons, generally of ⅜ inch a side, the rate of consumption of the carbons being about 3 inches per hour, the actual motor power per light ranging from 3 to 4 horse-power per hour, as indicated; while the intensity of the naked light produced has an hourly ordinary intensity (measured horizontally) of 1520 standard sperm candles with a single machine, augmenting to a maximum of 3040 candles when the two machines are coupled together. The annual cost of such lights, including engine power, carbons, wages of men, repairs, and interest at 7½ per cent. on first cost, is about 569*l.*; this is for a total of 4412 working hours during the year, and for a mean intensity of 1768 candles.

Lighthouses at Cape La Hève, Havre, France.—An Alliance electric machine is provided for each of the two lighthouses. Each machine is composed of six discs, of 16 coils each, and affords a light of about 1920 candles. The average annual cost, exclusive of interest, repairs, or depreciation, amounts to 660*l.* for both lighthouses. If for interest, depreciation, and repairs, 7½ per cent. were added, this would stand at 893*l.* The cost of maintaining a single light (in order to arrive at a precise parallel with the preceding case) is found to be 408*l.*, and

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for the electric light, *per se*, and not the entire amount requisite for the establishment of a lighthouse complete, has been taken into consideration. Consequently there will be a discrepancy between the figures given here and those in the works just quoted.

with interest as in the preceding cases to 525*l.* for a light of about 1920 candles intensity.

Lizard Lighthouse.—The Corporation of the Trinity House, in consequence of the recommendation of Mr. Douglass, supported by Dr. Tyndall, as the result of the experiments at the South Foreland already referred to, have established, January 1, 1878, at this their latest application of the electric light, a series of six Siemens dynamo-electric machines, each of the type "B" known as "6000 candles"; and these are driven by three caloric engines. Of the three electric engines thus formed, a single one may be driven, under ordinary circumstances, to produce one light of an hourly intensity of 3620 standard candles; or else the two may be coupled together, as is the case in thick weather, and an intensity of 8250 candles afforded to the light; the average amount of motor power per hour for a single machine being about three horses. The annual working expenses, under similar conditions to the South Foreland, came to about 500*l.* for a mean intensity of 4375 candles. The results at the Lizard point, therefore, to a more abundant light produced at a cheaper rate absolutely than with the older machines at Souter Point, at the South Foreland, and also than at Cape La Hève.

While considering these applications of the electric light to lighthouse illumination, it is but right to remark that they take place under circumstances and conditions special to themselves, and which do not exist in the case of industrial or other works. These arise in part from the paramount necessity of providing in the lighthouse an illumination of the most perfect character, and abundant in intensity; as well as of providing an amount of extra plant to guard against any cessation in the illumination.

The generally isolated situation of the lighthouse also adds to the cost of the materials employed, and causes the personal staff employed to be of a more skilled class, than where assistance in the matter of repairs is readily available. Any comparison, on purely economical grounds, between the electric illumination in lighthouses and in industrial works, must necessarily be unfavourable to the former.

Northern of France Railway Goods Station at La Chapelle, Paris.—This company, finding that the night-work done in the goods sheds and in the yard outside was very inferior in amount to that done during the day (about 37 per cent. per head), and that, moreover, a considerable number of small articles were mislaid and lost during the night-work, determined to try the electric light to improve matters.

A series of six single-light "Gramme" machines were provided, each of the size termed "A" (6000 candles), and a portable engine of 10 horse-power nominal. A special shed was erected to contain the electric machines and the engine. Several forms of lamp were tried, but that made by Serrin was ultimately preferred; latterly, however, a modification of that lamp by Suisse has been used with great advantage, as it allows of 12 hours' consecutive burning, in place of only 3½ with the original Serrin. The average length of the night-work was found to be 10 hours, with a maximum of 15 hours. The first outlay (intended for five light-centres) consisted of six machines, six lamps, portable engine, shed, conducting cables, &c.; this, fixed complete, amounted to 1420*l.* The electric lights were placed, one in a goods shed, the remainder in the open yard, so as to light up a row of turn-tables, where most of the night-work took place. The shed is 230 feet long, and 75 feet wide, with an open roof 33 feet high at the ridge, and 16 feet at the eaves, and having a central skylight along each side for most of its length; the upper portion of the walls and the under side of the roof were whitened to aid in reflection. The electric light is hung near to the centre, in a simple lantern of ground glass, and at an elevation of 15 feet from the ground. The result of this illumination was to increase the efficiency of the night-work by 30 per cent. The original imperfect gas illumination had been carried on by means of 21 jets, burning 4¼ cubic feet each. The new illumination was as effective as if these had been augmented to from 50 to 55, causing an hourly consumption of 220 cubic feet of gas. The light in the shed was found to give a good working light for a distance from it of over 100 feet, while those outside were satisfactory within a radius of 200 feet. The electric illumination commenced on January 15th, 1877, and has continued regularly ever since.

During this period a series of careful experiments were carried out by the officers of the company. The results showed that on an average nearly 3 actual horse-power was absorbed per light per hour, sometimes a little more, sometimes rather less; and that the square carbons, of ⅜ inch a side, were consumed at the rate of 4 inches per hour, or at a cost of 1½*d.*, waste included.

The nightly working expenses, with an average of 4 lights, and during 10 hours, were found to be—

	s.	*d.*
Motor power—8 cwt. at 20*s.* per ton*	8	0
Carbons—4 lamps × 10 hours × 1½*d.* (nearly) ..	4	10
Oil 8*d.*, wood 1½*d.*, lighting engine shed 2½*d.* ..	1	0
Engineman's wages	4	0
	17	10

This gives a price per light per hour of 5½*d.*; add to this 10 per cent. on first outlay of 1420*l.*, for interest and depreciation, 2½*d.*; total cost per light per hour 8*d.* This, to the railway company, would represent the cost of 22 gas jets; while the electric light, in the shed, was considered to have satisfactorily replaced 52 jets. Thus leaving an economy of 30 jets, or about 60 per cent. in favour of the electric light. Experience showed that the expense per light diminished as their number increased, and that the allowance for interest and depreciation (a considerable item when a machine had to be added for every light) formed about one-third of the working expenses.

The luminous intensity of each of these lights, measured on the horizontal, was found to be only that of 960 standard candles; though, owing to the downward-reflecting tendency of the light shed from these continuous-current single-light Gramme machines (a property already referred to in the preceding chapter), the mean amount shed might be taken at four times that amount. Owing, however, to its being centralized and concentrated within a limited area, the useful intensity did not exceed more than that of 52 Carcel lamps distributed (500 standard candles in all).

Iron-works of Messrs. T. and T. Powell, Rouen.— In the autumn of 1876, Messrs. Powell determined to illuminate a newly-made erecting shop with electric light. It is a building 125 feet long by 45 feet broad, with an open roof 26 feet high at the eaves, and 40 feet at the ridge. Two single-light Gramme machines of the "A" size, with two Serrin lamps, conducting cables, &c., were provided, and fixed complete for 196*l.* The lamps were suspended under the centre of the shed, 60 feet apart from each other, and at a height of 30 feet from the ground. No special motor was provided, the requisite power being taken from the engine which served to give motion to the tools, &c. A series of carefully taken indicator diagrams showed that, on an average, 2½ indicated horse-power was absorbed by each light, which was found to contain an intensity of 1824 candles (measured horizontally). This illumination (costing actually 4*d.* per hour per light) would come out, if with an allowance for a special engine and 12 per cent. for interest and depreciation, at a total expense for both lights of 2*s.* 10*d.* per hour; as against 7*s.* 7*d.* for an equally effective illumination with gas, at 7*s.* 8*d.* per 1000 cubic feet, the price in Rouen.

Messrs. Powell, after two years' experience of the working of the electric illumination, and finding it so much cheaper, more effective, and safer than gas would be in their erecting shed, have decided to extend it without delay to the rest of their works.

Albert Hall, South Kensington, S.W.—This large hall has been lit up very successfully on several occasions of late, commencing on February 13th, by means of five Siemens single-light machines, each of the type "B" of 6000 candles nominal, and supplying a small-sized Siemens lamp (the one shown in Plate III., Fig. 4); supplemented on two occasions, by way of experiment, by an alternate-current Siemens machine and generator (referred to at p. 26) feeding four Jablochkoff candles. The machines, outside of the basement of the building, are driven by the pumping engine belonging to the premises; which is of 24 horse-power nominal. The five Siemens lamps are suspended from the ceiling at a height of 150 feet from the floor, and are devoted to the illumination of the body of the hall; while the Jablochkoff candles, placed in the organ gallery, are reserved to light up the orchestra. They are enclosed in the ordinary opal glass globes in which they are usually placed; while each lamp is placed within a conical-shaped glass lantern, the lower part of which is darkened with white paint, and carrying above a glass shade, or reflector, rendered semi-opaque. The supply of carbons in the lamps is for six hours' burning. It will readily be noticed how advantageously the Siemens lamps are placed, at the most exceptional elevation of 150 feet above the floor. A glance at Fig. 1 of Plate IV. will show how the cone of intense light of each of these continuous machines will become fully developed thereby; and moreover how each of these pyramids of light, distinct though they are above, become blended and overlap one another down below, to the very great advantage of the illumination.

The following, it is believed, may be taken approximately as the cost of the production of the electric light during the four hours:—

	s.
Coals (1 ton)	20
Carbons (lamps 6s., candles 11s.) ..	17
Wages (3 attendants)	15
Wear and tear	8
	60

Or 15s. per hour.

The charge for the gas consumed during the time necessary for each performance (3½ hours), being 7*l.* 7*s.*, or 42*s.* per hour, the total consumption being about 42,000 cubic feet from the various star burners. It will be noticed how very large a proportion of the expense of "carbons" is due to the Jablochkoff candles.

A very considerable number of applications of this class of single-light electric machines, both of the Siemens and of the Gramme construction, exists in France and in this country, and serve for the illumination of industrial works differing very widely in character. The data, however, given in the above examples, together with those in the table on page 100, afford some test as to the capabilities and as to the working expenses of this class of machines.

All the previous examples have been of machines giving but a single light each; it will be interesting, therefore, now to describe a few cases where a number of lights are produced from a single machine.

Paris, Lyons, and Mediterranean Railway Company, Paris Terminus.—This company having decided to try the effect of the Lontin electric light, gave permission to the patentees of that system to enter upon a period of preliminary trial at their passenger station, to enable the company to judge of the efficiency and economy of the illumination before finally adopting it. Twenty-eight electric lights distributed about the station, and replacing 172 gas jets, were supplied with electricity by a combination of one generating and two dividing machines, all upon the Lontin system. The lamps used were the modification of the Serrin, introduced by M. Lontin, whereby a number can be employed upon one circuit (where only one of the original Serrin can be used). The power of each of these dividing machines was that known as of "18,000 candles." The motor power for this temporary arrangement was a Brotherhood 3-cylinder engine, supplied with steam from an old locomotive (lent by the railway company). This arrangement proved, however, to be wasteful in steam. The effective illuminating power of each electric lamp was considered to be equal to that of 80 gas jets. The average cost of the 28 electric lamps during these preliminary trials would appear to have been about 8*s.* 2*d.* (10·25 francs) per hour. This preliminary experience lasted from September 7th to October 28th, 1877. The result was, however, sufficient to satisfy the railway company as to the effectiveness of electric illumination, and as to the possibility of its being carried on without interruption, and it induced them to enter into a contract with the patentees of the Lontin system to light up, for a period of twelve months, a large receiving shed in their goods station of the same terminus, 330 feet long and 66 feet wide. Twelve lights were to be provided, all emanating from one dividing machine, and replacing 200 gas jets; the total cost per hour to be 5*s.* (6 francs), or 5*d.* (0·50 franc) per light; the contractors finding everything requisite, except water, and bearing all working expenses.

Western of France Railway—Paris Terminus, St. Lazare.—This railway decided, in the early part of 1878, to try the Lontin system of electric lighting at this station.

Goods Yard.—The patentees of this system commenced, in May, 1878, to light up the goods yard, on the arrival side. For this purpose, six electric lights are placed against the columns which carry the roof, at a height of about 12 feet from the ground. They are provided with electricity from a Lontin (double) machine, of the type known as of "12,000 candles." The motor power is afforded by an agricultural engine of 9 horsepower nominal, the piston being 9½ inches in diameter and 13⅛ inches stroke, the average pressure in the boiler being 83 lbs. per square inch, and 110 the average number of revolutions per minute of the fly-wheel, the total hourly consumption of coal being about 80 lbs. The lights were found, by a series of careful experiments, to be of a mean luminous intensity of 570 candles each. They are generally left naked, without any shade, without any ill effect being produced upon the persons below. The lamps used are the Serrin, modified by Lontin, so as to admit of several being placed upon one circuit; in this instance they are placed in pairs, six lamps upon three circuits. The consumption of the $\frac{3}{8}$-inch round carbons was found to be at the rate of 1½*d.* per light per hour.

The average working expenses of these six lights are, per hour—

	s.	*d.*
Coal, &c., for engine, at 32*s.* per ton	1	2
Carbons for six lamps	0	8
Engineman and stoker	0	10
Total hourly cost for six lamps	2	8

Or per light per hour, 5½*d.*

Passenger Station (Departure Side), "Salle des Pas Perdus."—In the month of June following, the directors of the railway company determined to extend the electric illumination to this portion of the station. Accordingly, the patentees of the Lontin light fixed for this purpose 12 lights, supplied from an "18,000 candles" Lontin machine; which was placed, together with an agricultural engine of 12 horse-power nominal, on the station itself, in a shed constructed for the purpose. The engine is of the following dimensions:—diameter of piston, 11⅞ inches; length of stroke, 13 inches; revolutions of fly-wheel per minute, 110; average boiler pressure, 93 lbs. per square inch. Each electric lamp is enclosed in a ground-glass circular lantern, in form of an inverted truncated cone, with a metal top to it; while the body of the lamp protruding below the lantern is placed in an ornamental bronze case, the entire having the appearance of an elegant moderator lamp.

The difference in the illumination between this side of the station and the goods yard side, where the lights are naked, is very marked, and leaves an impression very much in favour of the enclosed lights, which diffuse the illumination and render it more uniform. The effect in the large hall called the "Salle des Pas Perdus," which is

445 feet long, 66 feet wide, and 20 feet high at eaves, and nearly 40 feet at ridge, is very good. Five lamps along the centre, suspended at an elevation of about 18 feet from the ground, light up this fine hall. The twelve electric lights in this part of the station are placed upon three circuits; four lamps upon each.

Gaiety Theatre, London.—This example of the Lontin electric machine, from the prominent position in which it is situated, as well as from the length of time it has been established, together with its priority in this country as the first application in a regular way of a many-light machine, has attracted so general attention, that it is impossible here to pass it over without saying a few words upon it; though the particulars concerning it cannot pretend to have been collected with anything like the care and reliable accuracy which distinguish the previously quoted examples.

A Lontin "dividing" machine of the "12,000" nominal candle type (the one shown in Fig. 1, Plate II.), with its "generator," is established in the basement of the printing establishment of the 'Echo' newspaper. Its dimensions and capacity are those of the electric machine on the goods yard side of the St. Lazare Railway Station, in Paris; the performance of which may, therefore, be taken somewhat as a guide. One of the pair of horizontal engines in ordinary use to print the 'Echo' newspaper, is used to drive this electric machine. The engines are each, it is understood, of about 24 inches stroke, and 10 inches diameter of cylinder, and work at an average of 80 to 90 revolutions per minute with a boiler pressure varying from 35 to 45 lbs. per square inch. The lights provided from this machine are fixed in and around the Gaiety Theatre. They are six in number and are placed upon three circuits in the following manner:—one in Catherine Street, and another in Wellington Street, over the stage door, form circuit No. 1; the current passing from the former to the latter lamp over the roof of the theatre, and the return wire to the machine being laid over the roof at the back of the theatre. Of the three lights on the Strand front of the theatre, the two outside ones are upon circuit No. 2; while the central one, together with the one in the vestibule of the theatre, form circuit No. 3. The return wires from both these circuits to the machine are across again to Catherine Street.

The *mean* intensity of each of the six lights of the similar example to the present one at the St. Lazare Station, was found to be of 570 candles. Seeing that the machines in both cases are of the same nominal output, and that the rate of speed appears to be relatively about the same, it is probable that the luminous intensity of the lights will be much about the same at the Gaiety Theatre as at the Paris railway station.

Street Lighting in Paris.—The Jablochkoff "Candle."—Of the various streets and other places lit up by this system, the Avenue de l'Opéra is the one which, from its central position, has attracted most attention, and therefore will be taken here as a type example.

The Avenue de l'Opéra, including the Place de l'Opéra at one end, and the Place du Théâtre Français, are lit up by 62 lights; 46 single-candle, and 8 double-candle (on the Place de l'Opéra). These are divided into four groups; one on the Place de l'Opéra, two in the Avenue de l'Opéra, and one on the Place du Théâtre Français. Each group of lights is supplied with electricity from a "dividing" Gramme "16-light" machine, driven by an engine of 20 nominal horse-power.

A very considerable amount of mystery has been kept up by the patentees of this system as to the cost of it. The expense they state it to be is (1·06 francs) 11*d.*, nearly, per light, per hour, which they hope, so it is said, shortly to reduce by one-half.* The total remuneration by the city of Paris was (for this rate of payment terminated on November 30 last) 37·2 francs (29*s.* 9*d.*) per hour. The original gas illumination consisted of 344 jets, and cost 7·224 francs (6*s.*) per hour. The electric illumination is considered, however, as equal to 682 gas jets, say, to double the original illumination; that is, to a cost of 14·45 francs per hour, as against 37·2 francs for the electric one. The latter, therefore, cost 2·6 times that of the gas of equal illuminating intensity. The luminous intensity of each of these Jablochkoff candles, was found (as already stated) to be of a maximum of 290 candles; but, with the opal glass globe used in Paris, the *mean* power of each became reduced to that of about 115 standard candles.

The above details have been kindly communicated by M. Allard, the chief engineer of the lighting department of the city of Paris (under the engineer-in-chief, M. Alphand).

Many other applications of the Jablochkoff candles with

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* M. Th. Levy has latterly ascertained, for the municipality of the city of Paris, that the total hourly *net* cost of the 62 Jablochkoff candles in the Avenue de l'Opéra is as follows:—

	s.	*d.*
Steam power	2	6
Coal	5	4
Oil, grease, &c...	1	0
Wages	2	6
62 Candles at 5*d.*	24	10
	36	2

Or at the rate of 7*d.* per light per hour. The engine power absorbed by each light being taken at 1·25 horse-power indicated.

the Gramme machine occur in Paris, such as at the Magazins and the Hôtel du Louvre, at the Théâtre du Châtelet, at the Hippodrome, at the Hôtel Continental, &c. Still, as in none of these cases have the financial results been ascertained on such good authority as in the case of the Avenue de l'Opéra, it has been thought advisable to pass them over.

Street Lighting in London—The Jablochkoff Candle. —Coming after the preceding example in Paris, it will be interesting to compare the results of the same system in our own Metropolis.

Thames Embankment.—The Metropolitan Board of Works selected that portion of the Victoria embankment between Westminster and Waterloo bridges as the site of the trials of this new illuminant; which lasted from December 13, 1878, to March 13, 1879.*

The electric machine lent by the "Compagnie Générale d'Electricité" of Paris, being a "dividing" Gramme similar to the "16-light" machine in use in that city; here, however, it was somewhat more powerful, so as to supply 20 lights. A single-light "A" machine by the same maker serving as the "generator." These machines, together with the engine to drive them, were placed in a temporary shed on the west side of Charing Cross Bridge, and close to the station of the District Railway. The semi-portable double-cylinder engine, of 20 horse-power nominal, lent by the makers, Ransomes, Simms, and Head, was fitted with a very sensitive automatic governor; which, it is understood, gave considerable satisfaction throughout the entire period of the trials. The speed being unusually high, averaging 142 revolutions per minute; the diameter of each cylinder 10 inches, with 13 inches stroke, and an average boiler pressure of 50 lbs. per square inch. The speed of both electric machines seems to have been nearly the same; about 650 revolutions per minute. The extremely careful and solid way in which these machines were set upon ashlar blocks, as well as the regularity in the running of the engine, no doubt conduced much to the steadiness and absence of oscillation, which has been noticed in the lights produced. These lights were distributed upon four circuits; five upon each. They are placed along the river parapet wall, at intervals of 40 yards from each other. The distance from the machine to the farthest lamp towards Waterloo Bridge being about 600 yards; while that next Westminster Bridge is 700 yards away from the electric source, entailing an unusually long circuit.

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* These have, however, been extended for three months longer.

A very careful series of experiments as to cost, engine power consumed, and luminous intensity, have been carried out under the direction of Sir Joseph Bazalgette and Mr. T. W. Keates; the engineer and the consulting chemist, respectively, to the Board. They were intended to ascertain, amongst other things, the exact amount of engine power, taken under different conditions; as well as the intensity of the light, when naked, and with globes of divers kinds interposed. The effect of reflectors of various shapes has also been taken into consideration.

Holborn Viaduct.—About the same time that the trials just described commenced on the Thames Embankment, a similar illumination with the Jablochkoff candle was begun at the Holborn Viaduct under the control of the City Commissioners of Sewers, and under the supervision of Lieut.-Col. Hayward, the city engineer. Exactly the same type of Gramme machines have been used; though but 16 lights have been produced as in Paris, instead of the 20 on the Thames Embankment.

The motor power was a portable engine by Robey, of 20 horse-power nominal, which, together with the electric machines, were placed in a shed in Farringdon Street, alongside of the Viaduct. The lights were distributed on either side of the roadway along the Viaduct, except one at the western end of Newgate Street, which was central. Each lamp contained six candles, instead of four as generally is the case. The average distance between each pair of electric lights measured diagonally being 110 feet. It was found that the 16 electric lights replaced 86 gas lamps. The engineer in his report found, that the electric light cost about seven and a half times that of the gas; but that the illuminating power of the former was seven times that of the latter.

Billingsgate Market.—The Markets Committee of the Corporation, under the direction of the city architect, Mr. Horace Jones, authorized, almost simultaneously with the two previous examples, a four months' trial of the Jablochkoff candles; the machines, number of lights, and a Robey engine, were all identical with the last case. The engine and machines were placed in the vaults under the market; the 16 lights were distributed in and around it, as well as on the river front to light up the landing place. The number of electric lights was hardly found to be sufficient.

Westgate-on-the-Sea.—On December 2nd last year, Mr. E. F. Davis, having determined to try the Jablochkoff illumination on his building property at this place, commenced a trial with a 6-light Gramme divider with its generator, driven from a portable engine of 10 horse-power nominal, by Garrett. These experiments were carried out under the direction of Mr. W. H. Bennett and Mr. W. A. Valon, who have kindly supplied the following particulars:—

The six lights were erected along the Sea Road, the distance between the extreme lights being 400 yards, and at an interval of 80 yards from each other. Opal glass globes were used of two sizes, 20 inches and 17 inches in diameter. When the light through each size of globe was tested separately with the photometer, the illumination effected when using the larger globe was found to be very superior to that of the smaller one: 197 candles per light was the mean intensity found with the larger globe. This would tend to confirm the remarks made under the head of luminous intensity, as to the value of the enlarged size of the translucent globe in diffusing the light. The working expenses of the twenty-four nights over which the trial extended were *estimated* at 40*l*. 9*s*. 4*d*. for 96 hours' burning (or about 17*d*. per hour per light); of this amount nearly one-half being due to the candles alone. This very high rate of cost (even for Jablochkoff candles) was no doubt due to the small number of lights in use and to the shortness of the period of trial.

Perhaps it may be thought that too much space has been devoted to examples of illumination with the Jablochkoff candle. So much, however, just at present, is being said about these famed "candles," that it has been thought advisable to dilate somewhat upon this head. All the different examples, from places far apart though they are, agree upon two points: the extremely high rate of the cost per light, and the very small illuminating power given off in proportion to it.

Great Eastern Railway, Liverpool Street Station, E.C. —A series of six lights have been placed at this passenger station, on the platforms Nos. 9 and 10. These are supplied from a Wallace-Farmer machine, large size (the one shown in Plate I., Fig. 2), driven by a portable engine of 10 horse-power nominal. The lamps used are the Wallace plate-lamp, as modified by Ladd (Plate III., Fig. 7). The peculiarity attached to this example is that the lamps are all on one circuit; and the machine is a continuous-current one.

Owing to several interruptions, which have been caused, amongst other matters, by want of proper plate carbons, no sufficiently reliable observations have been as yet made. The defect already noticed as attached to this lamp, of extreme unsteadiness in the position of the luminous point, has certainly not so far been got over in this instance.

Rapieff Light at the 'Times' Office, London.—So much attention has, in this country at least, been drawn to this, one of the latest novelties in the application of the electric light, an interest due mainly to the peculiar form of lamp used in conjunction with the Gramme machine, that one can hardly conclude this brief notice of electric light applications without saying a short word about it. A Gramme "dividing" 16-light machine has been provided at the 'Times' office by the proprietors, together with an engine suitable even for future emergencies, and a portion of the lights, six in number, in the machine room, all in one circuit, have been set in place. A much larger addition to the number, in other parts of the building, is shortly contemplated.

Owing to the fact that only a portion of the intended application has so far been got to work, and that only recently (since October 12th last), it is not possible, nor hardly fair, yet to judge of the actual results. Still the system works fairly, and it may therefore be entitled to take rank as an established application of electric illumination.

In the preceding remarks on the various applications of electric lighting to illuminating purposes many, very many, of a highly interesting character have been omitted. Amongst these might be named those for military and naval purposes, for the construction of large works out of doors, such as docks, bridges, &c., for weaving and spinning operations (where the purity of the electric light is of peculiar advantage), for agricultural, and for other classes of night-work too numerous even to name. This omission has been necessitated partly from want of space, partly from want of those very careful and even scientifically prepared results which were desired. It is hoped, however, that the few and carefully selected examples presented will afford some slight guide as to the results, financial and otherwise, which effective electrical illumination may be expected to afford.

Economic Results.—By this is meant not a comparison of the money cost only, but one which includes the return in amount of effective illumination, which is obtainable by the several systems. This value can therefore only be arrived at from a consideration of the expenses, both working and of first cost, and of the luminous intensity which is yielded. Some information having already been given on both of these points from existing examples, a slight approximate attempt will here be made to endeavour to arrive at some general data on the subject. The same remark, as on the subject of motor powers, must be again strongly urged here; and it should also be borne in mind that no hard-and-fast rule, applicable even to all cases of the same class of machine, can be given; the circumstances varying so much in each particular case, that the results in no two applications can be precisely alike.

The two divisions into which considerations of this economic nature divide themselves are those of continuous and of alternate current machines. These become more marked because the former has also, practically so far, been itself confined to the production of single-light machines, while with the latter class rest the only successful applications of many lights from one machine; the few attempts with continuous-current machines to produce a series of lights have not as yet been stamped with results of such a nature as to be termed a success in actual practice. Then again the above distinction, in this its economic bearing especially, opens up the question of the loss supposed to be entailed by the subdivision of the light; a subject just at present occupying a good deal of attention.

The first point which naturally presents itself is, what is meant by the subdivision of the light; a matter about which there appears to be some difference of opinion. The product of each electrical circuit may, it would appear, be fairly considered as the unit of output. The supply to a single lamp may be made up of the combination of the different circuits of one machine, or of several machines put together. To separate each of these circuits, while preserving each intact for the supply of a single light, would not, in the writer's opinion at least, be a subdivision of the light. But to break up a circuit, or unit, so as to enable it to support more than one light would be to subdivide it; the number and intensity of those lights, whether large or small, forming merely different phases of the subdivision. It is the loss, or difference, which the output of a current when supplied in an unbroken whole to a single light, bears to the sum of the different fractional supplies, that it is desirable to ascertain with some degree of approximation; if not of accuracy. Its economic results would naturally be expressed in candle intensity available, and in the cost, both working and of first outlay, attending the different cases.

It was mentioned, at the commencement of the remarks on luminous intensity, that the amount of light given off was affected, amongst other things, by the nature of the lamp used. This is the case most markedly with the three classes of lamps working, either by the voltaic arc, by incandescence, or by both combined. Regulators represent the first of these classes, "candles" are a type of the last named, and the incandescent lamps of the second.

A very great difference, at least as far as the author's experience goes, exists between the relative luminous intensity given off by the same machine from a single light, according to whichever of these classes of lamps is used. The output of a machine with regulators does not readily divide itself (except with the Serrin-Lontin and Rapieff ones); while with candles and with incandescent lamps subdivision is easily and always adopted. Some of the statements which appear to afford evidence of a very great loss due to subdivision of the light, are misleading from a disregard of this difference between the luminous output of the several classes of lamps. The intensities of each of a number of, sometimes "candles," sometimes incandescent lamps, and the total of those intensities, is very naïvely compared with that of a single regulator used with the same machine. To the reader unaware of the relative difference in the results of the several kinds of lamps, the loss by subdivision, when put in this way, appears enormous.

But what approximately is the difference in the luminous result between the three classes of regulators, of candles, and of incandescent lamps?

Comte Th. du Moncel has found, that when a Serrin-Lontin regulator and a Jablochkoff candle were placed at the same time each upon a circuit of a Lontin machine (care being taken that the circuits were quite equal to each other), the light given off by the former was about three times that of the latter. This result is about the same as that arrived at by the author. The relative values of the luminous results per horse-power, as given off in a single light from the same machine, seem to be somewhat approximately represented by 15 for regulators, 5 for candles, and 1 for incandescent lamps; while the proportionate standard candle result per horse-power would be as 900, 300, and 60 standard candles for each respectively and taken in the above order. Differences which surely should be borne in mind, and distinguished from each other.

With regard to the relative value of the divisibility of the product of each class of lamp, the following reliable data have been obtained.

Regulators.—At the St. Lazare Station in Paris, already several times referred to, with Serrin-Lontin lamps:—

No. of Lights.	Mean Intensity of each Light.	Sum of Mean Intensities.	Machine.		Lamp.
	candles	candles			
6	570	3420	Lontin, 12-light, alternating currents.	3 circuits used, in quantity, 2 lights upon each.	Serrin-Lontin.

Candles.—In obtaining the following observations, through the kindness of Messrs. Edmundson, Westminster, the author received the valuable assistance, in taking the photometric measurements, of Mr. A. Ayres, the Assistant Engineer of the Trinity House.

No. of Lights.	Mean Intensity of each Light.	Total Mean Intensity.	Total Net Horse-power absorbed.	Machine.		Lamp.
	standard candles	standard candles				
1	652	652	2·59	Gramme, 6-light, alternating currents.	2 circuits only used (out of 4), and coupled up into one; in tension: of a total length of 100 yards.	Jablochkoff candles.
2	634	1268	2·78			
3	518	1554	2·89			

It must be noted, that the luminous intensities arrived at in these experiments are necessarily very much higher than are those arrived at from the actual street lighting in Paris and in London; where the number of lights is greater, and the circuits much longer.

Incandescence.—The following particulars are given by M. Hippolyte Fontaine,* as having been arrived at with Reynier lamps at Messrs. Sauter, Lemonnier and Co.'s workshops in Paris:—

No. of Lights.	Mean Intensity of each Light.	Total Mean Intensity.	Machine.		Lamp.
5	143	715	Gramme "A," single-light; continuous current.	One circuit, in tension; of a total length of 110 yards.	Reynier.
6	124	744			
7	95	665			
10	48	480			

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* 'Revue Industrielle,' Nov. 27, 1878.

University of Michigan General Library

An inspection of the above examples does not seem to warrant the assertion, that, as far as luminosity is concerned, a considerable loss is due to subdivision. As to expenditure of engine power, its increase is certainly not proportional to the augmentation obtained in the light by adding to their number. This would point to a sensible diminution in the ratio of the working expenses to each light, by an increase in the number of the latter. As the item of carbons is of course directly proportional to the number of lights, this diminution must be in the ratio of engine-power per light.

The item of depreciation and interest upon prime cost should also be taken into consideration in the divisibility of the light, as against the production of the same number of lights by a series of single-light machines. Thus while the six lights in the first example, if provided on the Lontin or the De Meritens system, would entail but one machine; to do so by a series of Siemens or of Gramme single-light machines would require six of them. In the latter case the prime cost of the several machines would exceed considerably that of the single one required in the first case; while the augmented amount of driving power required by the series would quite counterbalance any excess of light each might give off over that emanating from the single electric machine. With regard to the second example, as also in the third, a decided gain in luminosity is obtained by increasing the number of lights (within certain limits).

The amounts of the luminous intensities in each of the three classes of lamps should, as already mentioned, be kept distinct; except as a guide in the selection, as to which class should prove to give the most economical result in any particular application.

The following Table presents, it is hoped, some data as to the economic working of a few of the electric machines.

Electric Machine.					Engine Motor.							Remarks.		
—	Standard Candles per Light (measured horizontally).		Revolutions per Min.	Lamp used.	Nature.	Fly-wheel Revolutions per Min.	Cylinder.		Horse-power per Light.			Locality.	Observer.	—
	Total.	Per H.P. absorbed.					Diam. Ins.	Stroke. Ins.	Nominal.	Actual. Gross.	Actual. Absorbed.			
Holmes	1523	476	400	Holmes	Steam	..	13	18	10	..	3·2	South Foreland	Douglass	Magneto-electric. Alternating currents.
Alliance ..	1953	543	400	”	”	..	”	”	10	..	3·6	”	”	
” ..	3000	667	400	Serrin	”	..	..	..	..	..	4·5	Paris	Allard	
Meritens, large	8600	1228	650	Holmes	Gas	156	9	16	8	10·9	7·0	Royal Institution, London	Douglass	
” small	1860	1240	880	Duboscq	”	156	9	16	8	4·2	1·5		”	
Siemens, medium	4100	1254	850	Siemens	Steam	..	13	18	10	..	3·3	South Foreland	”	Dynamo-electric machines. Single-light, continuous currents.
	..	..	..	”	Gas	158	9	16	8	8·9	5·4	London Stereoscopic Co.	Amos	
Siemens, small	..	..	..	”	”	156	9	16	8	8·2	4·7		”	
Gramme, single light “A”	960	320	..	Serrin	Steam	115	..	..	12	3	2·7	La Chapelle, Paris	Northern of France Railway.	
” ”	1824	730	920	”	”	..	..	..	..	..	2·5	Powell, Rouen	Powell	
” ”	2850	1018	892	”	”	..	..	..	..	..	2·8	Paris	Tresca	
” ”	2520	740	930	”	Gas	143	6¾	12	3·5	5·1	3·4	Edmundson, Westminster	Shoolbred	
” ”	705	383	800	Brush	Steam	..	6	8	..	..	1·84	Philadelphia	Franklin Institute Committee.	
Large Brush	1230	377	1340	”	”	..	6	8	..	..	3·26	”		
Small ”	900	239	1400	”	”	..	6	8	..	..	3·76	”		
Large Wallace	823	..	800	”	”	..	9	18	..	..	..	”		
Small ”	440	113	1000	”	”	..	6	8	..	..	3·89	”		
Gramme, dividing; 16 lights	250	..	640	Jablochkoff.	”	..	..	..	20	..	1·25	Avenue de l'Opéra, Paris	Allard	Many-light, alternating currents.
Gramme, dividing; 20 lights	..	..	650	”	”	142	10	13	20	..	..	Thames Embankment	..	
Lontin, dividing; 6 lights	570	..	350	Serrin-Lontin.	”	110	9½	13⅛	9	..	..	St. Lazare Station, Paris	Western of France Railway.	

CHAPTER VIII.

PROSPECTS OF ELECTRIC LIGHTING.

That the use of electricity for lighting purposes has passed beyond the stage of mere experiment, so as to be successfully applicable in certain cases and under certain conditions, can hardly be doubted, if the numerous industrial establishments, such as ironworks, cotton mills, railway stations, both goods and passenger, to which this illumination has been applied in France, for lengthened periods and with results satisfactory in every way, are taken into consideration. But it must be borne in mind, that these solutions all belong to a very small class of illumination, each and all exacting conditions of a certain peculiar type; and not at all common to the ordinary illustrations of lighting. The principal of these requirements for these cases, where large expanse of area is perhaps the distinguishing feature, are an abundance of light, in such quantities as to be almost unattainable except at considerable expense with gas, and where the absolute steadiness and noiselessness necessitated for close and continuous examination is not demanded. It is only to such large areas, requiring powerful centres of a rude form of light, does electric illumination pretend so far to have found a satisfactory commercial solution.

An exacting and over expectant public has nevertheless demanded, nay required imperatively of it, that it should forthwith solve with success the other and more delicate problems of illumination; and this despite the warnings of those who know its capabilities best. That these successive solutions will be arrived at in due time and with the advance of science, there is but little room to doubt, both as to street lighting and as to that of large interiors; and even ultimately as to the more difficult problem of domestic illumination. But that there are still many, very many obstacles, on the score of economy, of combustible electrodes, and others which have been noticed in these pages, as well as inconveniences in the form of want of steadiness, and of noise in the lights produced, no one is more aware than are those practical electricians, and others, who in many directions are endeavouring to remedy them. There is, however, one point on which justice is hardly done to electric illumination. It is as to the comparative cost of its production with that of other illuminants; with gas most especially. It seems to be hardly borne in mind, that the electric light, as an industrial application, is still in its early infancy; and that all expenses attending it are at the best on a retail scale, if not even on an experimental one. While at the same time it is pitted against gas, which is manufactured at a wholesale price, and with all the improvements consequent upon half-a-century of production. If electricity enters the lists of competition against gas it must of course be exposed to this disadvantage. But still the above facts seem hardly sufficiently to attract attention; though it must be remembered also, that from this very cause considerable improvement with practice is in store for the electric illumination.

Another considerable drawback to the introduction of this new illuminant, is the heavy first cost of plant for its production; that is, it is a relatively heavy one for individual consumers, and where the expense attending the introduction of another form of lighting has already been incurred.

Much has been said as to the sanitary improvement in the condition of large rooms, by the substitution of the electric light for gas. It is well known that in many rooms, both large and small, more fresh air is required to dilute the injurious products of combustion of the gas, than is needed for the respiration of the audiences sitting there. The great relief afforded by the electric light from the heat given off by the gas jets, despite the intense temperature of the voltaic arc, will be due to the very small space it occupies; and consequently to the much diminished volume of air which has access to it. The electric flame does not present, probably, a quarter of the surface of that of a gas jet; whilst perhaps fifty gas lights may have been replaced by the single electric one. It seems to have been somewhat hastily assumed, that the products of combustion arising from the electric spark are innocuous. The recent researches of a very able chemist, Mr. T. Wills, have enabled him to state as his opinion,* that the very high temperature of the electric spark causes the oxygen when burnt to form compounds of nitrogen, probably fumes of peroxide—gases which are very deleterious to health. Still, even if this were so (and Mr. Wills speaks somewhat hesitatingly as to the exact nature of the gases developed), the small number of the electric lights likely to be used in a room, and their necessarily elevated position, would render it no difficult matter to carry off any gases developed by combustion; as, for instance, those from a gas sun-light are got rid of. Moreover, as it is hardly probable that a non-combustible electrode would cause such noxious gases to be developed, at least in any abundance, the very fact that the use of carbon electrodes led to the development of such baneful emanations, would hasten the introduction of some incombustible electrodes,—a circumstance which would certainly be the most effective means of rendering electric illumination of more extended, and indeed of general, application.

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* See 'Journal of the Chemical Society,' Dec. 19th, 1878.

Great fears have been expressed (and recently in a very tangible financial form) as to the future position of gas-distributing companies, in view of the adoption of electric lighting. Much has been said, and by very eminent electricians too, as to the separate and distinct fields, which doubtless belong to each form of illumination. But while taking up each its allotted sphere, a certain portion of the larger illuminations, the wants of which have been in many cases but ill supplied, will no doubt have to be resigned by gas; each day, however, fresh applications and uses of it as a motive or as a heating power, are opening out, and which may, and probably will, prove more than a set-off.

For purposes of the distribution of artificial light certain bodies, whether private companies or municipal corporations, have been legally entrusted with that duty; and large sums of money, representing the vested interests of a very large section of the public, are absorbed in the execution of this work. Nor is it probable, speaking generally, that such functions will be lightly taken away from those bodies, on account of an improvement in a new form of illumination, and which is applicable under certain circumstances and to a limited portion of the sphere of action of those bodies. But to ensure such extension of legal privileges, it must be shown, that the improvement is readily accepted and will be made use of by them as a step of progress; and not churlishly, and with a dogged determination to throw every obstacle in its way.

Recently the subject of electric illumination has been engaging, and naturally so, the close attention of the largest of our gas companies, the Gas Light and Coke Company; and a series of careful experiments and observations have been undertaken under its direction to ascertain the bearings of the matter. Much disappointment, not to say pain, has in many quarters been caused by the unwillingness to allow the report thereon to be made public (as if fearing its contents), and at a feeling akin to bias, which has been allowed, perhaps unwittingly, to pervade the experiments. It is felt by some, that an opportunity has been allowed to pass away, by which a large and powerful body empowered to distribute artificial illumination, might have made itself acquainted with, and, without being absolutely friendly, might have obtained some control over an improvement to which some place necessarily must be assigned within its own domain. To be in a position to be ready to introduce the change itself, when opportune, rather than let it be forced upon it by others, has been deemed by some persons a course which might in the end have been better for the Company itself.

That improvements in street illumination should be made by the gas companies when put upon their mettle, was only natural, and there is plenty of room for an amelioration. It is a question of the relative price at which such improvement can be effected. The tendency for many years has been in all illuminations to concentrate, and to intensify the light-centres; as for instance the very general introduction of sun burners with gas, instead of a number of isolated jets. The point at which this concentration shall most beneficially cease seems the chief question at present. With gas the tendency is to accumulation, while with electricity it is to reduction in the intensity of those centres. The matter will resolve itself most probably into a matter of comparative expense. The actual intensity in each particular case will of course vary; but for street lighting, and for the interiors of public buildings of the ordinary size, light-centres of from 200 to 500 candle power will probably be found to be the most suitable. The very frequent occurrence of illuminations affording this abundance of light, which electricity readily supplies, is gradually accustoming the public to it; and who will end in demanding a standard of a more liberal character than is at present in vogue. But if this more liberal supply of artificial light is adopted, gas, at anything like its present price, will have considerable difficulty in eventually competing economically with electricity. It being understood of course, that this is not to be interpreted by the extravagant cost of the Jablochkoff system (against which the gas companies have been most fortunate to be pitted), but with some of the other methods, of which there are several which are quite applicable, and at a much more reasonable rate of expense.

Take for instance, the improved gas illumination along Waterloo Place, Regent Street, with its series of footway lamps of 80 candle-power. It is a question, if, with cannel gas at 4*s.* 4*d.* per thousand cubic feet, as stated to be used, this illumination has not reached the financial limit between the two systems. Any considerable augmentation in the abundance of the light supplied would throw the balance of economy in favour of the electric light—of course, supposing that the above price of gas be maintained; while the electric lighting expenses are certainly capable of considerable reduction, as experience will show. In fact, with each system very considerable financial and other improvements can be effected.

Whatever be the limits within which these two illuminants, gas and electricity, eventually confine themselves, one result will certainly follow; an improvement in the character, as well as a cheapening of illumination generally, from whatever source it may come. The general public will be the gainer thereby, and will be less under the influence of a monopoly, in the matter of artificial light, than it is at present; while the world of science cannot but feel pleasure at a further progress realized in the application of its principles to general industry, and to the common welfare.

The author cannot conclude these pages without expressing his sincere thanks to all those gentlemen, who have aided him in the collection of the varied information contained in them. There is hardly a name mentioned, of those now connected with the subject, whether as men of science, as inventors, or as manufacturers, but from whom the author has received some kindly assistance. Though it seems almost invidious to name any one in particular, where indebted to so many, he cannot but thank most especially Mr. James N. Douglass (Engineer to the Trinity House), M. Allard (Inspector-General of French Lighthouses), M. J. Allard (Chief Engineer of the Lighting Department of the City of Paris), and M. Lartigue (Northern of France Railway), for the aid each has always so readily afforded him.

The subject of the application of electric lighting is one of such recent date, and its two main branches, the electrical and the mechanical, have hitherto been so little brought together and considered as one, that the author feels some diffidence, especially as to the latter part of his work, in putting it forward in its present form. It must, however, be considered as an attempt to collate, and to somewhat arrange, the data necessary for a true appreciation of the entire subject. Many gaps are still waiting to be filled: much information and many details exist, to which the author has not had access, or of which he is not cognizant. He hopes, therefore, for the kind forbearance of his readers, in dealing with these deficiencies, or even, it may be, with mistakes. While he also trusts that they, on their part, will be good enough to communicate to him any information, which will enable him to add to, or to correct, the details contained in these pages.

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